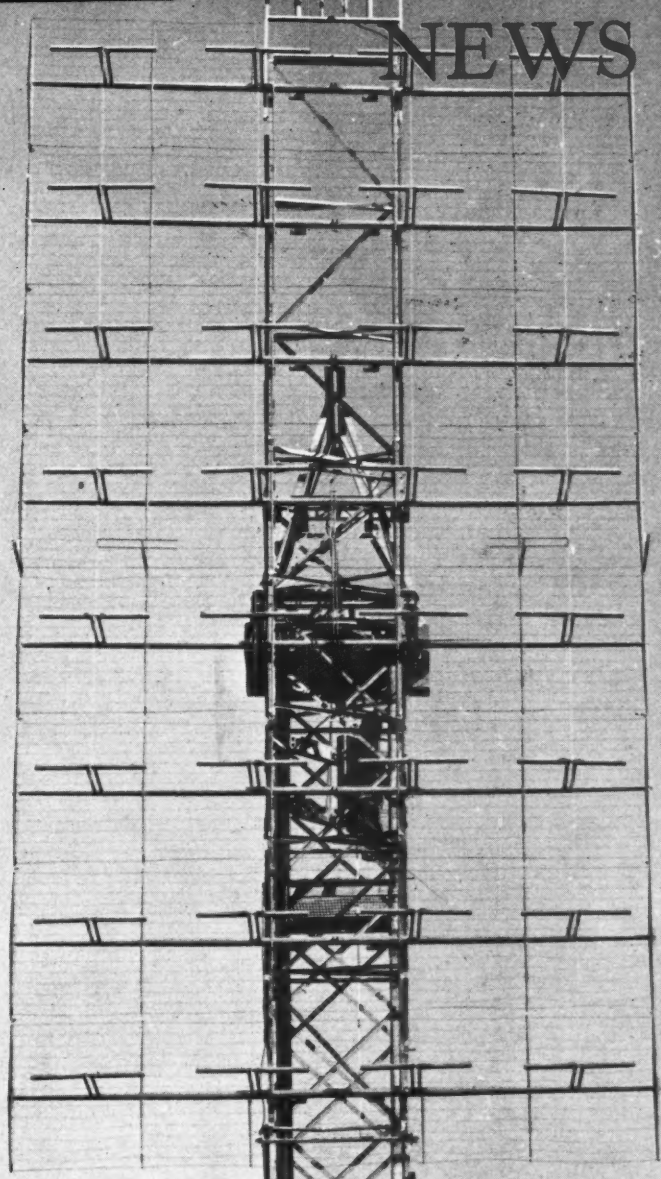
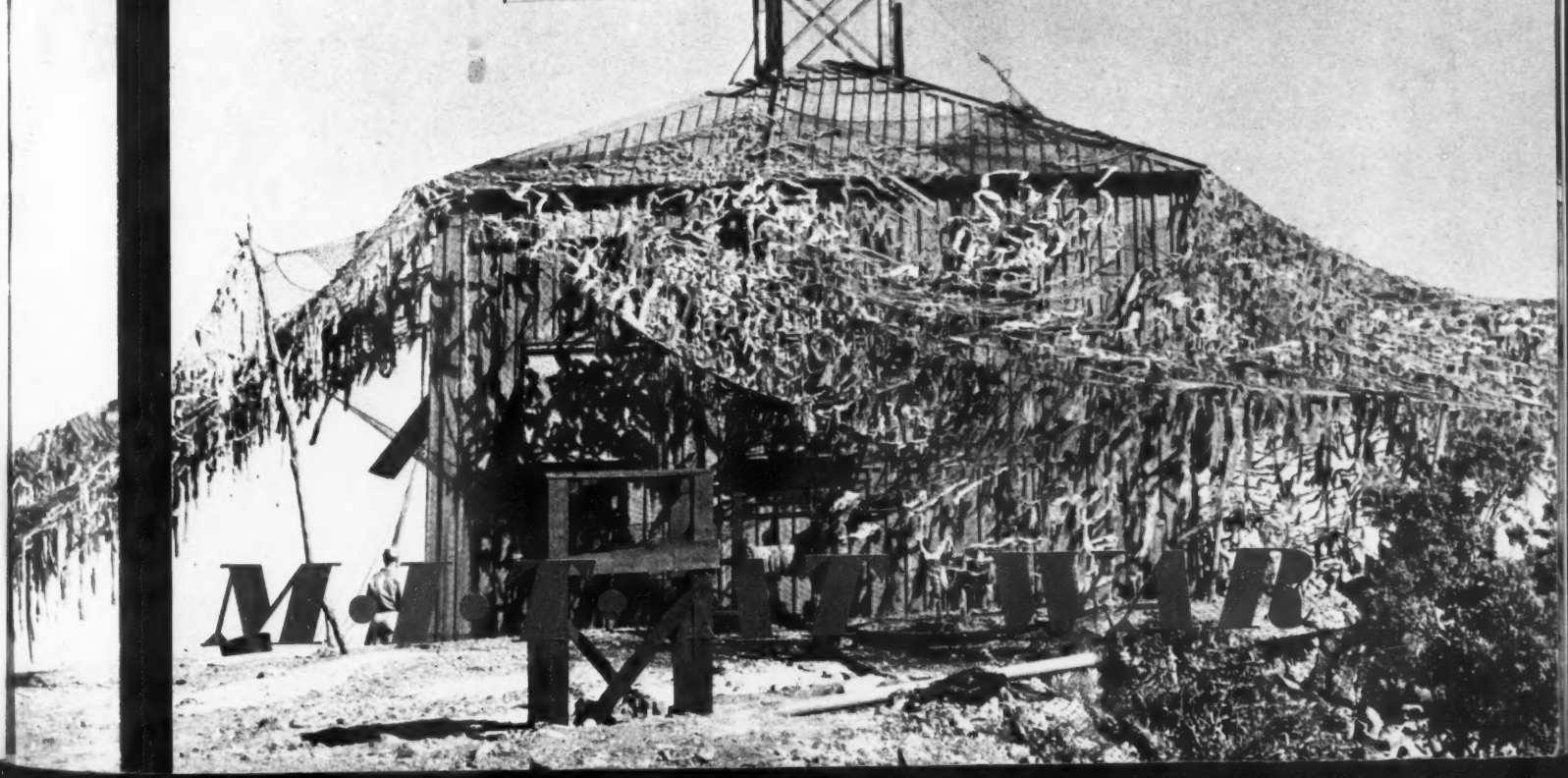
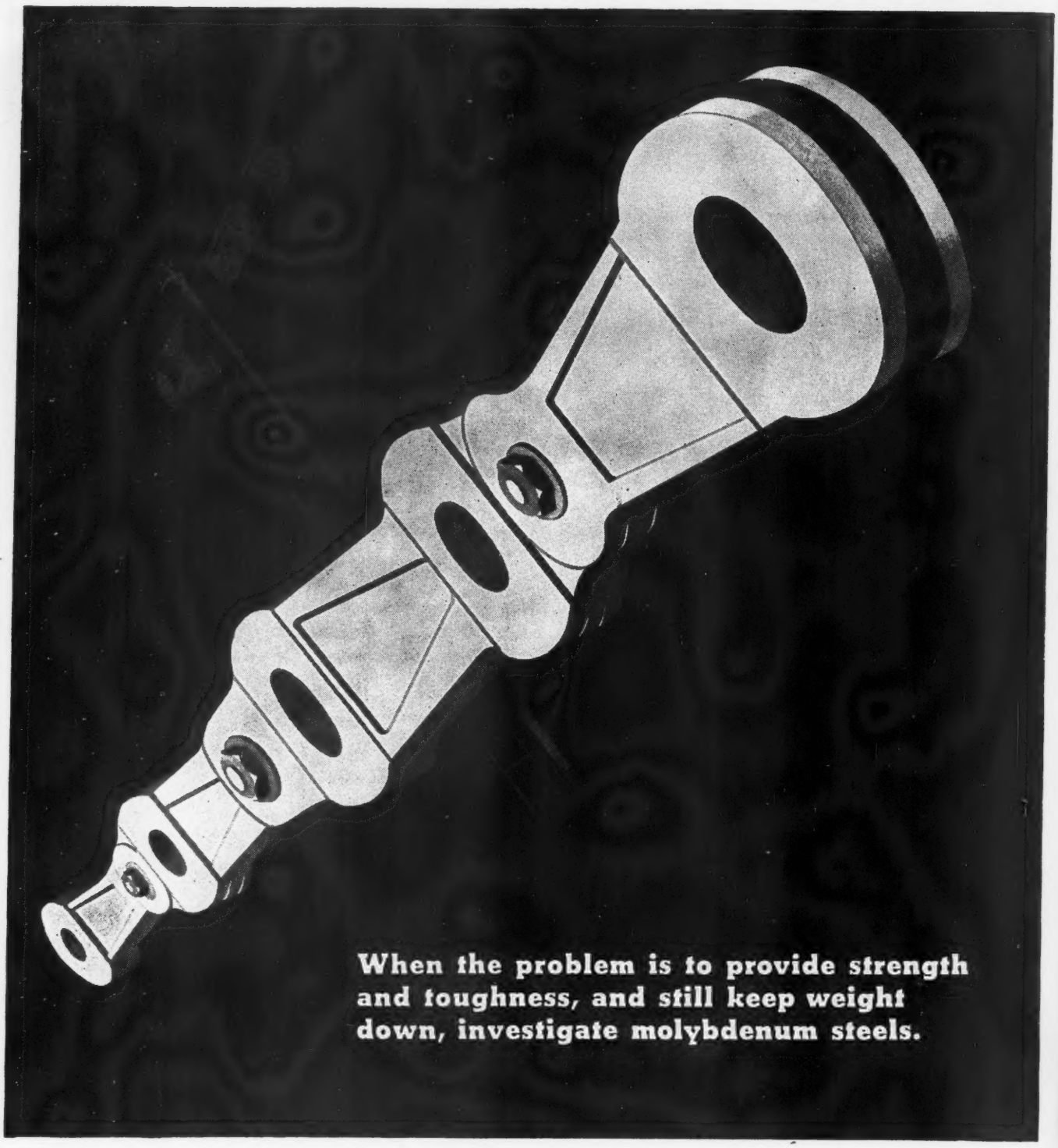
DECEMBER, 1945
VOL. XXVII—NO. 4
TWENTY-FIVE CENTS

The TECH ENGINEERING NEWS







When the problem is to provide strength and toughness, and still keep weight down, investigate molybdenum steels.

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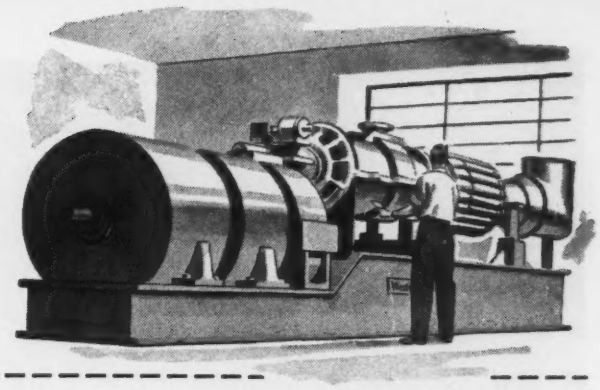
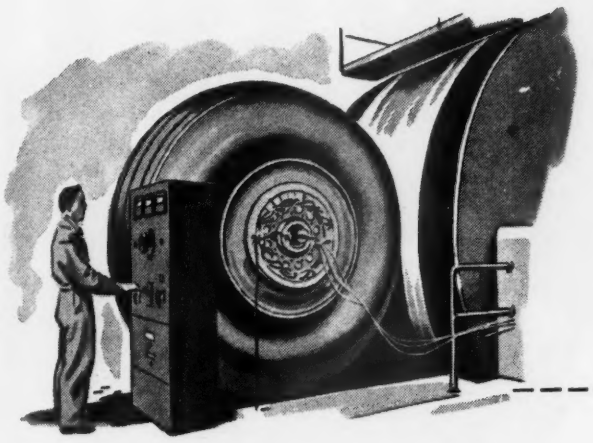
MOLY

In a laboratory a SCIENTIST experiments with a new gas turbine . . . using heat-resisting alloy blades that are far stronger, at 1100°F., than *ordinary* steel at room temperature.

. . . the name on the GAS TURBINE is Westinghouse.





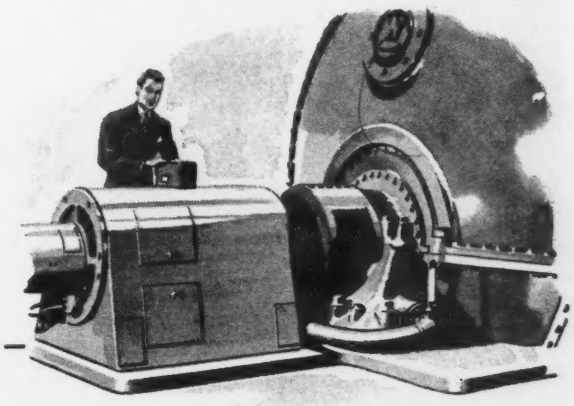
On a special machine a TESTER employs a Rototrol* for smoothly accelerating a large flywheel, used in determining the wear-resisting qualities of tires and brakes—for huge air transports of the future.

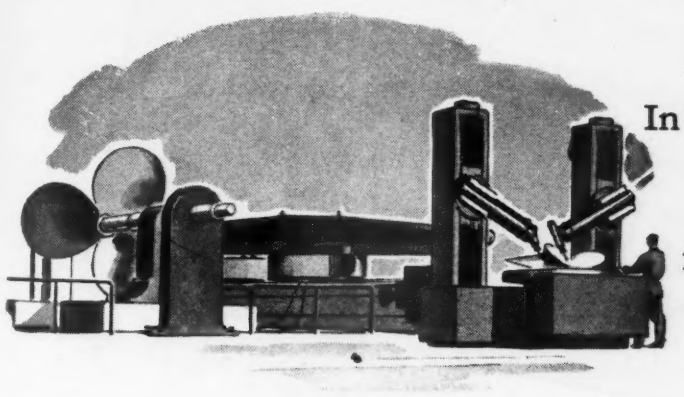
. . . the name on the ROTOTROL is Westinghouse.

*Registered Trademark

In a power plant an ENGINEER uses a Vibrograph to "take the pulse" of a turbo-generator . . . recording the smallest vibrations as a trace on a film.

. . . the name on the VIBROGRAPH is Westinghouse.





In a manufacturing plant an OPERATOR uses an electronic control to regulate the movement of milling cutters—for accurately machining irregular contours on giant ship propellers.

. . . the name on the ELECTRONIC CONTROL is Westinghouse.

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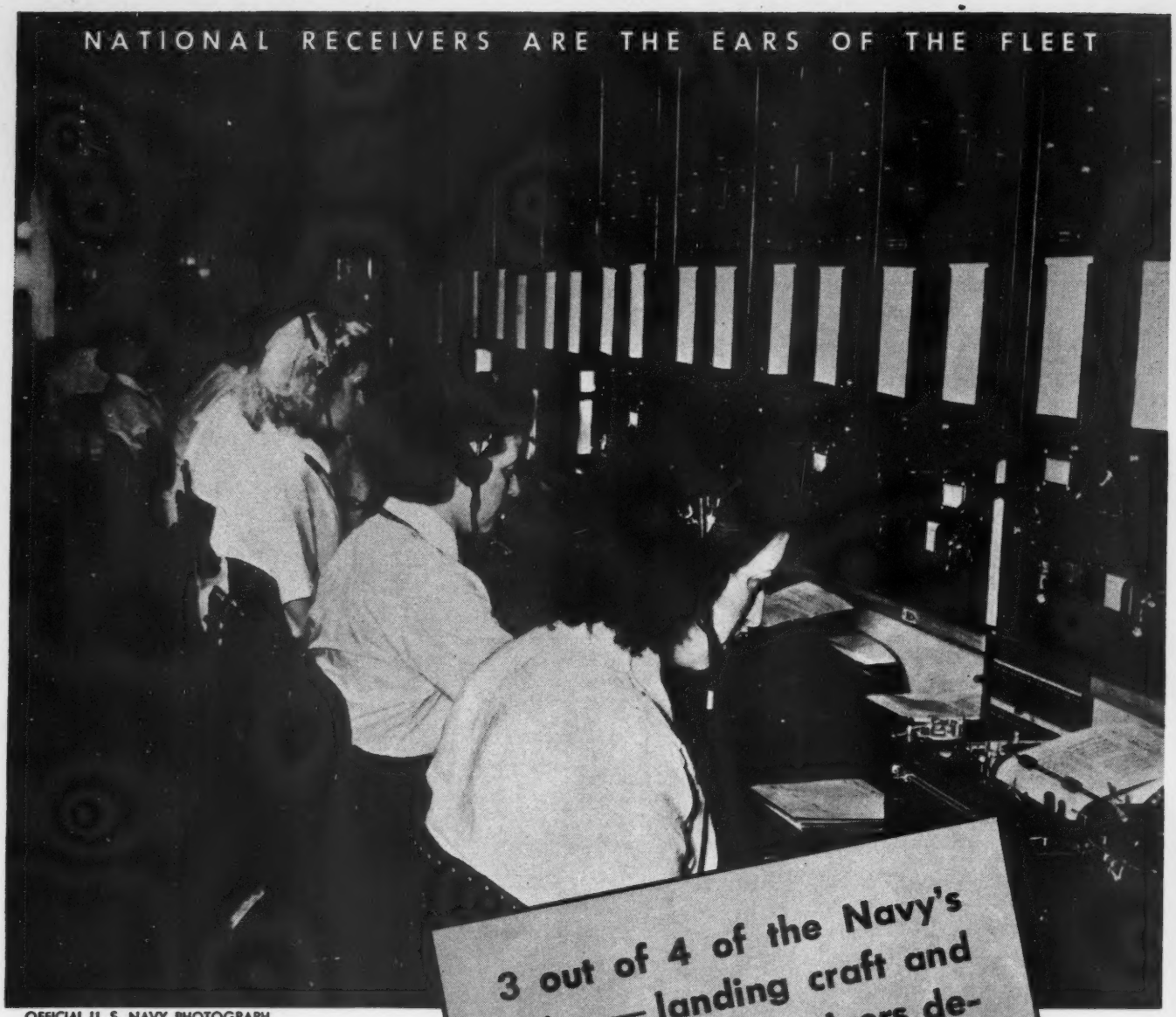
NATIONAL RECEIVERS ARE THE EARS OF THE FLEET



OFFICIAL U. S. NAVY PHOTOGRAPH

3 out of 4 of the Navy's ships — landing craft and larger — use receivers designed by National. Shore stations use them too.

The picture above shows Waves in the radio room of the U. S. Naval Air Station, Floyd Bennet Field, New York.

HRO

NC-200

NATIONAL COMPANY

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NATIONAL RECEIVERS ARE IN SERVICE THROUGHOUT THE WORLD

The TECH ENGINEERING NEWS

PROFESSIONAL JOURNAL OF THE UNDERGRADUATES

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Volume XXVII, No. 4

DECEMBER, 1945

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All pictures, unless otherwise noted, were taken by staff photographers, or supplied by Institute agencies

MEMBER OF THE ENGINEERING COLLEGE MAGAZINES ASSOCIATED

Published monthly during the school year at Walker Memorial, Cambridge 39, Massachusetts, by the undergraduates of the Massachusetts Institute of Technology. Entered as second class matter, at the Post Office, June 1, 1920, at Boston, Mass. under the Act of March 3, 1879.

Copyright 1945 by The Tech Engineering News.

Subscription per year $1.50. Foreign $1.75. One copy 25 cents.

OFFICE OF THE PRESIDENT

To Readers of the Tech Engineering News:

For almost five years the staff of the Institute has devoted its entire energies to training and research for war purposes. The research, as well as some of the training, has of necessity been under the shrouds of secrecy, and The Tech Engineering News is performing an important service in publishing a summary of those phases of the research here that have been released from security restrictions by the sponsoring agencies.

Scientists and engineers from over 140 other educational institutions and industrial companies have contributed immeasurably to the success of all of the program carried on under Institute auspices. The record of accomplishment depicted in the following articles demonstrates the valuable results that can be attained by bringing together technical personnel of divergent backgrounds to cooperate on a single objective. The effective teamwork of scientific groups at the Institute and in other research centers throughout the United States, together with those maintained by Britain and Russia, permitted the Allies to hold technical superiority throughout the war. The same spirit will assure continued progress in technology in peace.

I know that these articles will serve to encourage and stimulate the young men now studying in the fields of engineering and science to accept the challenge and opportunity offered in the years ahead.

Cordially yours,

Karl T. Compton

Karl T. Compton

Radiation Laboratory

COMPILED FROM SPECIAL RADIATION LABORATORY RELEASES

MOST of the radar used by the armed forces had its origin in the M. I. T. Radiation Laboratory, where thirty-eight hundred members worked in secrecy on research and development of this equipment.

Operating its own plant of buildings and its own airport at Bedford, Massachusetts, on loan from the Army Air Forces, and with field stations scattered at many points over the United States and both sides of the world, the Radiation Laboratory began in November, 1940, in a few rooms assigned to it at M. I. T. With a budget of $4,000,000 a month, and with a staff of scientists and engineers who comprise an estimated twenty per cent of the nation's top-rank physicists, it has grown from a group of about two dozen men to an organization which, though operating in secrecy, exceeded in size the staff of a major university or a nationally known corporation.

The task assigned to the Radiation Laboratory when it was founded was the development of microwave radar — that is, radar working on higher frequencies than had ever been used before. Many competent men thought at the time that it could not be done. Still others thought that, though it could be done, it could not be done fast enough to play a part in the war. Since that time, the Army and Navy have contracted with private manufacturers for about two billion dollars worth of radar sets based directly on Radiation Laboratory research. And "microwave" radar has made obsolete nearly all of the longer-wave types.

In addition to doing research and coördination on this volume of manufacture, the Radiation Laboratory very early began to act as its own manufacturer, building small numbers of radar sets of its own design in emergency cases where there was not time for manufacturers to tool up for large-scale production.

These "handmade" sets were important in many critical phases of the war. In the winter of 1943–44, the Eighth Air Force was led by a dozen Radiation Laboratory blind-bombing sets. Only five months intervened between the Eighth's request for these sets and the first raid led by them. Production models of these sets reached the Eighth by spring. A single radar set of another type, based on the ground and having a very high power, was an important factor in spotting buzz-bombs so that fighters could shoot them down.

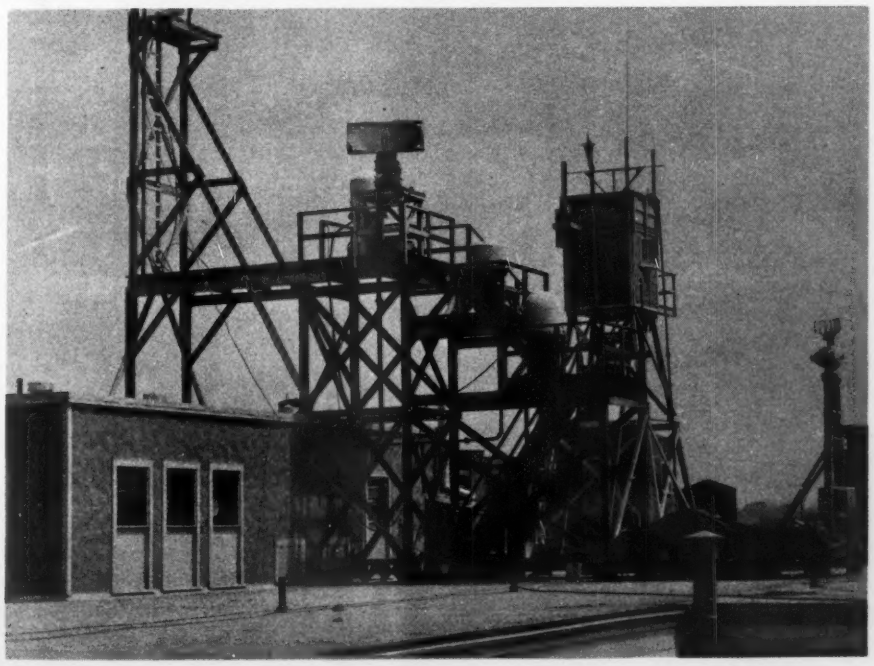
This same high-power radar was also useful in enabling effective ground control of tactical fighters and bombers; and so highly was it valued that it took a decision by Prime Minister Churchill to get the set away from the RAF anti-buzz-bomb fliers so that General Patton could use it for his tactical air command on the Continent.

The Radiation Laboratory was founded as the result of a chain of actions that began in the National Defense Research Committee in 1940. Dr. Vannevar Bush, then head of NDRC, set up a special section whose duty was to develop detection devices of all sorts, and appointed President Karl T. Compton of M. I. T. as head of this special section.

At that time radar was well known to all the major nations and was in active use. But it was longer-wave radar. President Compton therefore appointed a committee to explore the possibilities of microwave radar. This "Microwave Radar Committee," under the leadership of Alfred L. Loomis, a lawyer, financier and scientist of New York, gathered some engineers who had worked at M. I. T. under Professor E. L. Bowles and Professor W. L. Barrow. It had begun an exploration of the problem, when the British sent over a scientific mission headed by Sir Henry Tizard.

The British mission in the summer of 1940 was an important landmark in the history of radar. The British scientists brought with them a development of their own, called the magnetron, that was capable of generating microwaves of a power theretofore unknown. They left the magnetron at the Radiation Laboratory, together with one of their own representatives. The Microwave Committee then decided that the problem was important enough, and promising enough, to require a laboratory of its own with wide powers and a large staff.

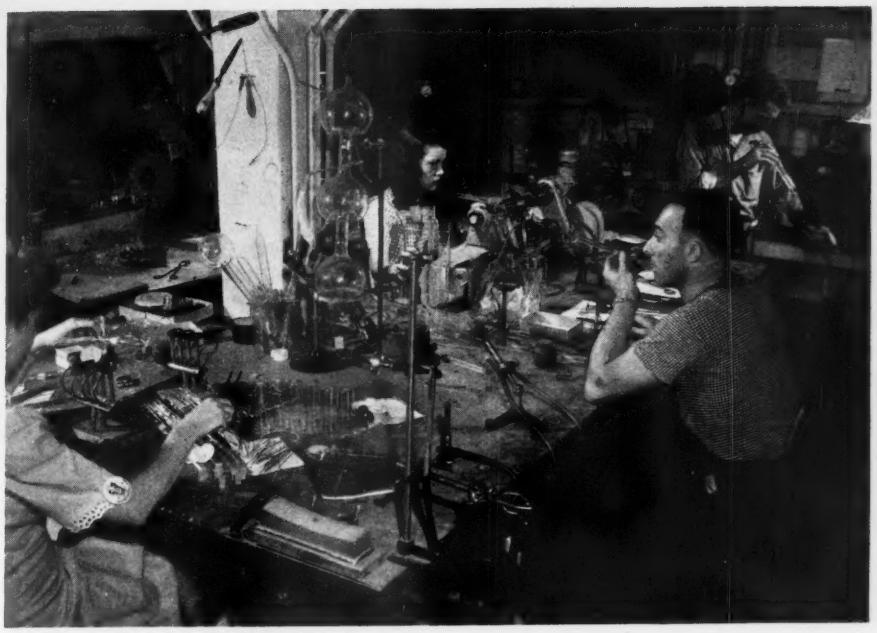
Experimental radar antennas atop M.I.T.



In October of 1940, Dr. Lee Alvin DuBridge of the University of Rochester was selected as Director of the proposed organization; President Compton agreed to give it a home at M. I. T.; and the name "Radiation Laboratory" was chosen as one that would describe the duties of the organization in a general way, but would not reveal anything important about its purpose or its special interest in this new and secret kind of radar.

The Radiation Laboratory was not made a part of M. I. T. in the way that a university laboratory is usually part of its parent body.

Installing experimental airborne radar on a B-24



Blowing special tubes

Although located on M. I. T. grounds, and with its business affairs administered through M. I. T., it was made an independent institution under Dr. DuBridge, working directly through the Microwave Committee and NDRC, and establishing its own channels for coöperation with the armed services and with industry.

Within three weeks after his appointment, Dr. DuBridge had recruited a dozen or so of the country's ablest scientists. This group, the nucleus of the present establishment, was organized into five main groups, each group doing research on one of the five main parts of a radar set. The groups were headed by Dr. I. I. Rabi of Columbia (Dr. Rabi is now Associate Director of the Laboratory), Dr. L. A. Turner of Princeton, Dr. W. M. Hall of M. I. T., Dr. K. T. Bainbridge of Harvard, and Dr. A. J. Allen of the University of Pittsburgh. Later, Dr. L. W. Alvarez of the University of California was made head of a newer group, to direct the assembly of the separate parts into a complete system.

On November 11, 1940, the new group got its first specific assignment: design of an improved night-fighter radar. Work was immediately begun.

Almost from the first moment, the Radiation Laboratory realized that work could not be confined to a single problem. Early in the testing of the night-fighter radar, Laboratory workers noticed that the set had many unsuspected advantages over previously known sets in spotting ships on the surface of the sea. Accordingly work was begun on a "sea-search" modification of the night-fighter set.

Even before going into this new adaptation, the Laboratory had begun work on a radar set that could follow aircraft with sufficient accuracy to permit effective blind anti-aircraft fire. This set later turned out to be one of the most useful radar sets of the war. It was used for control of aircraft, for shooting down buzz-bombs, and for many other purposes beside that for which it had been designed.

And finally, the Laboratory began to redesign radar's basic parts to produce wavelengths even shorter than the British had achieved. These new tasks, plus other possibilities that became app rent almost every day, indicated that a drastic expansion was required. Dr. F. Wheeler Loomis of the University of Illinois was then asked to become Associate Director of the Laboratory. In addition to taking charge of the recruiting and handling of the personnel, Dr. Loomis assumed almost the entire administrative load, leaving Dr. DuBridge free for technical work.

By the time Pearl Harbor was past, the Laboratory was well set in the path it was to follow through the rest of the war. To its initial responsibility for basic radar research, it had added an increasing amount of engineering and small-scale construction. To fill the need for rush construction of radar sets to bridge the gap while industry got production rolling, the Research Construction Corporation set up a division in Cambridge. This was operated almost as a branch of the Radiation Laboratory. The Laboratory also had important responsibilities in the coördination and standardization of parts and equipment, and did much to bring together the products and practices of the entire electronics industry. It did this by coöperative committees which also included Army and Navy representatives.

In addition to all this, the Laboratory had begun to act as a civilian advisory branch of the armed services.

Army and Navy officers visited the Laboratory, bringing new requirements for radar; Laboratory people fanned out over the country, visiting electrical manufacturers, staying at research laboratories and test grounds in the armed services, gathering and redistributing information on new devices and on military problems these devices would be called on to meet.

In the summer of 1942, the Laboratory's "sea-search" radar (the offshoot of the first night-fighter set) was patrolling the Atlantic in United States and British planes. Production sets resulting from it are credited with fifty per cent of the U-boat kills in the Atlantic. And by this time, the Laboratory had literally scores of projects on its books. There was no longer any doubt as to the effectiveness of "microwave radar."

Hundreds of scientists began to be added to the membership of the Laboratory. The housing problem in Cambridge became acute. Internally, the adminis-

(*Continued on page 132*)

The original "Early Warning" set leaving the Radiation Lab on its way to England

C. W. S.

By SIDNEY L. SMITH, 2-47

ONE of the largest and most extensive of the military research installations at M. I. T. during the war was the Chemical Warfare Service Development Laboratory, second in importance only to the combined units of the Radiation Laboratory. Here in Building 12, built originally for the Chemical Engineering Department, were carried on the research programs and development work which set the pace for the world in the war of chemicals.

History and Organization of the Laboratory

Plans for this installation were commenced more than four years ago, in the fall of 1940, when Colonel Bradley Dewey, representing the Chemical Warfare Service, began to investigate the possibilities of establishing such a laboratory here at M. I. T. It was recognized at that time that in the event of war the existing C. W. S. laboratories, located at Edgewood Arsenal in connection with the Aberdeen Proving Grounds in Maryland, might prove inadequate for the work they would be called upon to do, or would certainly be critically overcrowded. Also, it was felt that some dispersion of the C. W. S. activities might be wise, so that the research work of the over-all program might not all be concentrated dangerously in one limited area.

Therefore, it was decided that some supplementary installation should be set up to act not so much as a research laboratory alone but rather as a development unit which would serve to coördinate the Army-directed research with the actual industrial production. Cambridge was finally determined upon as the location of this new laboratory, since here the Army technicians could be augmented and assisted by the great number of scientists and their staffs of trained personnel already at work at M. I. T., Harvard, and the others of the many schools and universities in the Boston area, as well as by the engineering staffs of New England's varied manufacturing plants.

After some negotiation, the Chemical Warfare Service secured the use of Tech's proposed new Building 12, which had been intended as a laboratory plant for the use of students in Course X, since their present floor space in Building 4 had grown distressingly congested and inadequate for the expanding program in that department.

Under the command of Colonel Jacquard Rothschild (then a captain), the new laboratory was officially activated in June of 1941; the small staff of five officers and a secretary were then housed in temporary quarters — two rooms in the basement of Building 4. However, by November of that year the staff had been enlarged and transferred to its ultimate home in the newly constructed Building 12.

The rapidly expanding staff was separated into divisions, each with its own chief, which functioned as either executive control, service, or research units. Each division was composed of sections which in turn were headed by group leaders. In this way, the closely knit organization was enabled to engage efficiently in the wide variety of projects assigned to the laboratory.

The executive division had supervision of all the laboratory's work and the responsibility for the purchasing and administrative duties. There were a number of service divisions including a library of books on chemistry relative to the varied work on hand; an editorial group which handled the publication of the laboratory reports; a photographic laboratory and printing shop; a glass-blowing shop; a stock room for glassware and all the other incidental laboratory equipment; a tool crib; an analytical division; and an engineering division including the drafting rooms and the machine and carpenter shops. These latter two divisions occasionally solved research problems in their own fields, but their chief job was still to service the other divisions. The research divisions were separated into groups in order to handle various types of work such as chemical engineering and chemical development.

The directors of the various executive, service, research, and development groups and a fairly large portion of the staff of the laboratory were officers of the Chemical Warfare Service, chemists and engineers drawn from all over the country. The laboratory also employed a great number of women technicians and trained others as laboratory assistants, draftsmen, and operators of various specialized equipment or instruments. These workers were cited in an official account which read, "The enthusiasm and faithful attention to the job shown by these women proved to be a major factor in the successful operation of the laboratory."

Also among the personnel of the laboratory staff were men employed as shop technicians, carpenters, and mechanics. Trained civilian chemists were employed in some cases as research associates and assistants, and, in addition, several students from M. I. T. and the neighboring colleges found temporary employ-

Taking measurements for new gas masks

ment in the laboratory. The author of this article worked there for some months this summer as a technical assistant, coming into personal contact with much of the work that was being carried on. To one studying chemical engineering the experience proved a most interesting ordeal and possibly instructive.

The laboratory was assisted in its work by members of the Institute staff, including Professors Scott Walker, Harold Weber, and Roy Whitney of the Chemical Engineering Department, and many others who acted as consultants in problems related to their individual fields.

Research and Development

When the laboratory began its work in 1941, the broad expanse of Building 12 seemed more than ample for its needs. But such a great number and variety of projects were assigned to it that soon the large central well of the building was built in with additional floors of plywood-partitioned units to accommodate the overflow from the original and permanent rooms and laboratories. Eventually this main building was supplemented by a number of smaller storage or experimental installations scattered over the vicinity and had its own warehouse located nearby.

The research work itself covered a wide field of the Sciences, ranging from work with the newest discoveries of electronics to the study of anthropology and mycology.

One of the most important projects of the laboratory was its work on gas mask development, which the Army centered exclusively at M. I. T., culminating finally in the production of the Army's new and widely publicized combat mask. For this remarkably light, hoseless mask was especially designed a fully protective lightweight cannister as well.

In conjunction with this work an extensive anthropological survey was made on the men in the Army to determine just what shape of mask would fit every soldier and require the least number of sizes. Not only were measurements of head and face taken, but also casts were made of all the types of head-shapes that seemed most prevalent. Many of the laboratory staff "lent" their heads in this study.

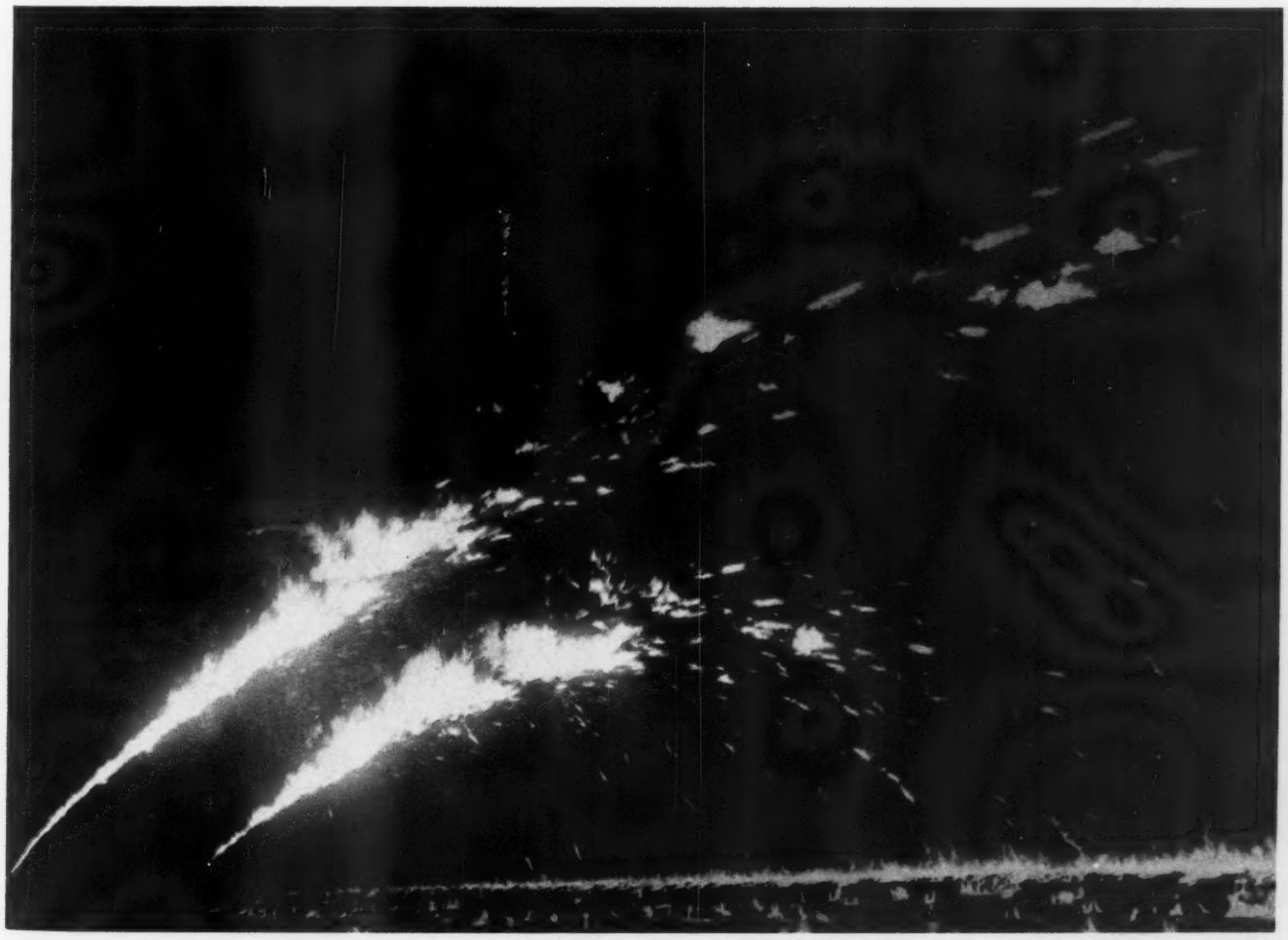
Also connected with the gas mask development was the study of captured enemy masks in order to compare them with our own. A similar comparative examination was made of a great deal of enemy equipment and material.

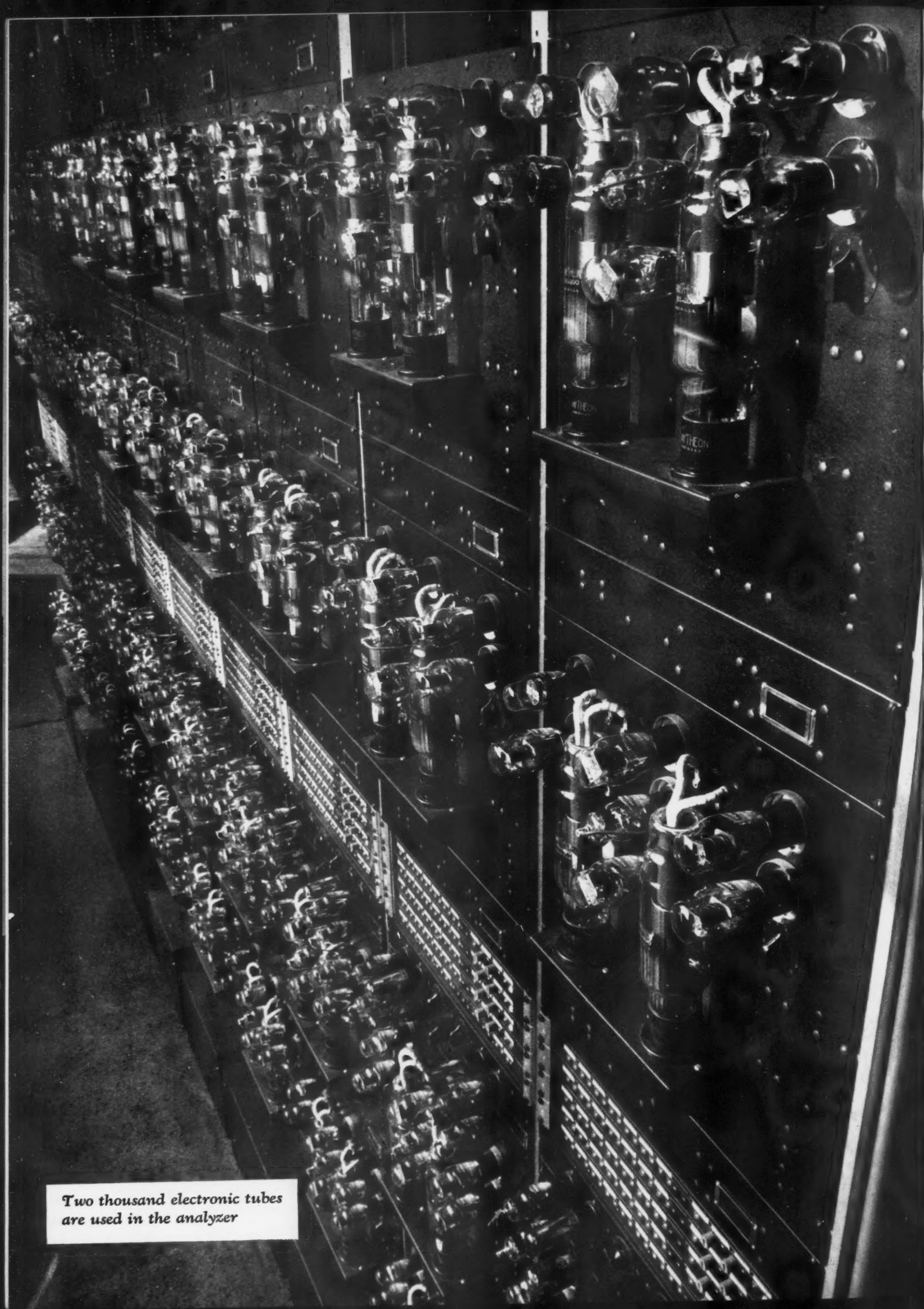
In the manufacture of gas masks, as well as many other articles used by the Chemical Warfare Service, a serious problem was caused by the scarcity of natural rubber. Consequently, a section of the laboratory was engaged in the development and compounding of rubber synthetics to be used in protective coating, impregnation, and molded items. Improvements were made in coated and impregnated gas-resistant textiles, and a group studying fabrics developed a fireproof cloth that can be laundered and yet retain its non-inflammable properties.

Another of the research programs carried on by the laboratory dealt with a number of troublesome fungi recently encountered by our forces in the Pacific area. The necessity for improved mildew control and fungiproof materials became apparent soon after our first Pacific campaigns; the results of the research on this

(*Continued on page 141*)

Flame throwers undergo experimental development in Lawrence factory





Two thousand electronic tubes are used in the analyzer

The Center of Analysis

BRAINS AND GEARS. Computations of the range tables for the new naval guns and ammunition, calculation of antenna patterns and characteristics of wave propagation and absorption, and determination of statistical correlation coefficients were only a few of the war jobs performed by the automatic calculating devices developed and operated by the M. I. T. Center of Analysis.

The Center's staff, which numbered over forty during the war, was headed by Professor Richard Taylor of the Department of Electrical Engineering, in the absence of Professor S. H. Caldwell. Main parts of the Center's equipment are, of course, the two famous differential analyzers. A great variety of complicated manually operated computing machines are also included in the apparatus. The purposes of the Center of Analysis are three: Instruction, Research and Development, and Operation.

INSTRUCTION. Regular classroom and laboratory courses are given in the use of mechanical calculators, work starting with the abacus and culminating in the differential analyzer. Special restricted courses in fire control are taught naval officers, but the press of war work cut down instruction opportunities even for these men.

RESEARCH AND DEVELOPMENT. The first differential analyzer was designed at M. I. T. in the 1920's by Dr. Vannevar Bush, former vice-president of the Institute and now head of the Office of Scientific Research and Development. The original model was called the "product integraph"; this machine integrated the product of two given functions in the manner of a watt-hour meter.

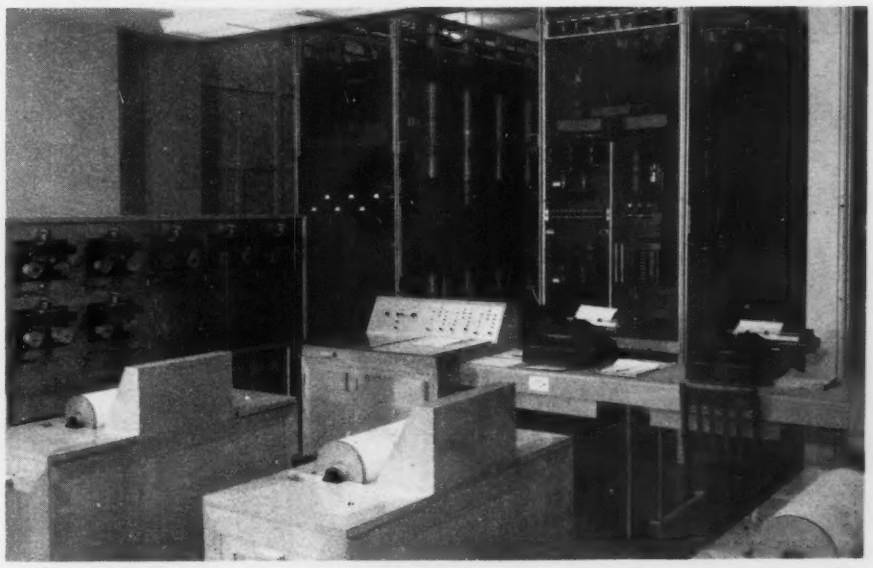
Technology's first real differential analyzer is still operating on the fourth floor of Building 7. Its picture is familiar to all TECH ENGINEERING NEWS readers. Integration is performed by the wheel-and-disk method. All connections between various parts of the machine are made mechanically; herein lies the principal disadvantage of this analyzer. In some cases so much time is required to set up a problem on the device by hand that, although the actual time consumed in solving a problem is small, the total labor involved does not give the differential analyzer an advantage over other methods of solution. It follows that it is quite difficult to switch rapidly from one problem to another.

The new analyzer, however, while using the same wheel-and-disk integrating method, is able to set itself up automatically to solve a problem. Cumbersome mechanical connections have been replaced with electrical ones throughout. The problem statement is punched in code on tape by a special machine looking somewhat like a large typewriter. This tape is then fed into relay devices (shown at the extreme left in the photographs) which actuate the necessary parts of the differential analyzer.

After the machine is set up, actual control of the analyzer's operation is centered on the two small panel boards shown mid-way back in the picture. To the right of these panelboards can be seen the ordinary electric typewriters (one for each of three separate problems which the analyzer can solve simultaneously) which type the final results in column form. Each stand mounted by a large cylinder (depicted in the foreground of the photograph) corresponds to one of the typewriters. Stretched on the cylinder is a graph which gives an overall picture of the progress of the solution. Separate servomechanisms housed in the right and left thirds of the stand actuate motion along the two axes of the graph.

Professor S. H. Caldwell

The new analyzer, showing input relays at the far left



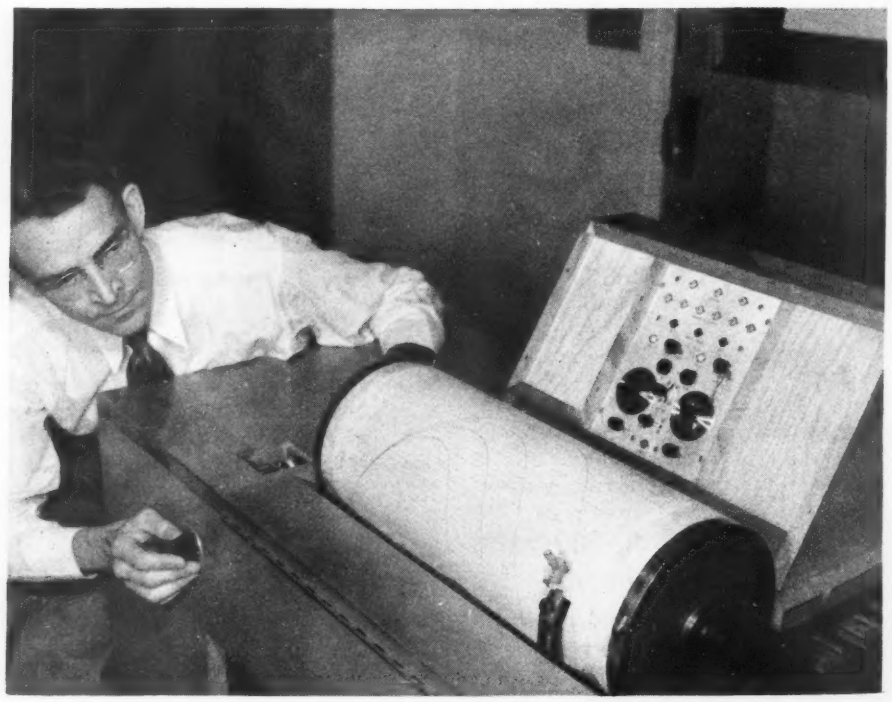
Transmitting the problem statement to input relays by means of perforated tape

A still newer development in differential analyzers was in initial stage before the war: the design of an almost completely electronic analyzer. Such a machine would eliminate inherent disadvantages of mechanical devices. Until completion of this new differential analyzer (now estimated at five or ten years hence), additions and improvements will continue to be made to the existing equipment.

OPERATION. Work for the Government and for the Institute itself has been carried out continuously during the war, but no routine commercial jobs have been undertaken. The Center of Analysis has, however, been called upon repeatedly to give advice on computing problems or even to build special apparatus for outsiders. Actual operation of the Center's machines not only gets necessary tasks done, but also provides a proving ground for new ideas. Current jobs have not yet declined from their wartime peak, since some Government work is still to be finished, and the influx of new problems is high.

The coöperation of men from many different departments at the Institute made possible, under the impetus of war, such great advances in machine calculation that opportunities in this field are now of a magnitude beyond anything yet undertaken.

— LOUIS B. WADEL, 2-46.



Here the machine draws curves representing the trajectories of shells fired at targets at various distances

Cyclotron

By STANLEY RUTTENBERG, 10-46

Diagrams by the Author

Why Cyclotrons Are Built

A cyclotron is a device which can accelerate ions to high energy without the use of excessively high voltages. The beam of ions can then be used to bombard targets, which, in fact, is the main use of cyclotrons. By virtue of the construction of a cyclotron and the factors which make it work, the stream of ions is focused and is usually concentrated in a sharp beam, the intensity of which can be varied from a few to several hundred micro-amperes. Although only about one ion in a million penetrates to the nucleus of the target atom and produces a nuclear reaction, enough ions concentrated on a small area can produce a sufficient quantity of radio-active materials to separate chemically. These radio-active materials are used in medical and physical research, as well as in medical pathology. The cyclotron also can produce large amounts of fast neutrons which can be studied, or used to bombard other materials.

How It Works

Consider an ion of mass m and charge q, moving with constant speed v in a magnetic field H. If its motion is perpendicular to the lines of force of the magnetic field, it will experience two forces: a magnetic force pulling the ion perpendicular to its path and to the magnetic field, and a centripetal force opposing the magnetic force. If the motion of the ion has no component parallel to the magnetic lines of force, the resulting path is a circle lying in a plane perpendicular to the lines of force:

$$F = Hqv = mv^2/r, \text{ or } r = (m/q)(v/H),$$

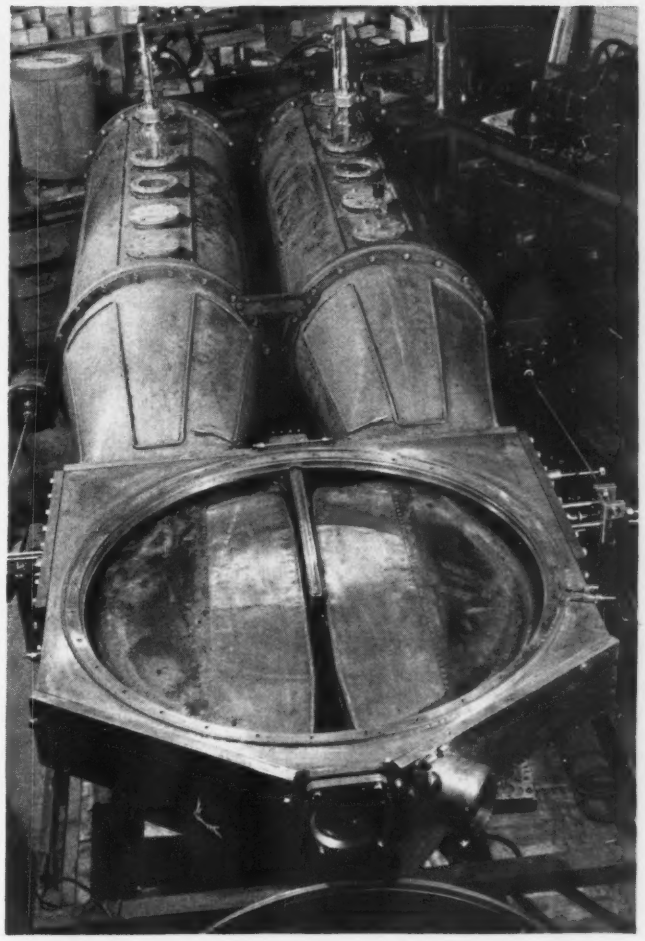
where r is the radius of the circular path of the ion. By rearranging this equation, we find that

$$v/r = H(q/m)$$

or, in other words, that the angular frequency of the ion is independent of its velocity and is a constant if the magnetic field H is constant (both q and m are constants of the ion except for relativity effects). Now we provide an electrical field along the diameter of the circular path, so that it will accelerate the ion along this path, and we reverse this field periodically with the same angular frequency as that of the ion. Because the angular velocity of the ion is a constant, at each half revolution it will receive an acceleration from the electrical field, and, moreover, will remain in phase no matter what the magnitude of the acceleration may be.

The principle of operation, therefore, is extremely simple: all that is required are two hollow electrodes, called dees from their resemblance to the letter D, placed face to face in an evacuated chamber mounted between the pole pieces of a magnet. Ions starting from a source in the center of the arrangement will be successively accelerated by the voltages on the dees, and will be pushed to high velocities by the time they describe circles the size of the dee structure. The only adjustments required are that the electrical frequency and the magnetic field remain constant at the values prescribed for them by the "resonance" equation given above.

In actual operation, however, to yield a useful number of high speed ions, a cyclotron must have provision for focusing the ions, to keep them moving in the central plane of the chamber and dee system. Proper design of the dee electrodes will make lenses of the electrical fields, and magnetic focusing can be obtained by tapering down the magnetic field slightly from the center outwards. The practical upper limit of energies available from the cyclotron is set by the effect of relativity upon the mass of the ion; when the mass increase with velocity becomes appreciable, the resonance equation shows that the angular velocity of the ion is no longer constant.



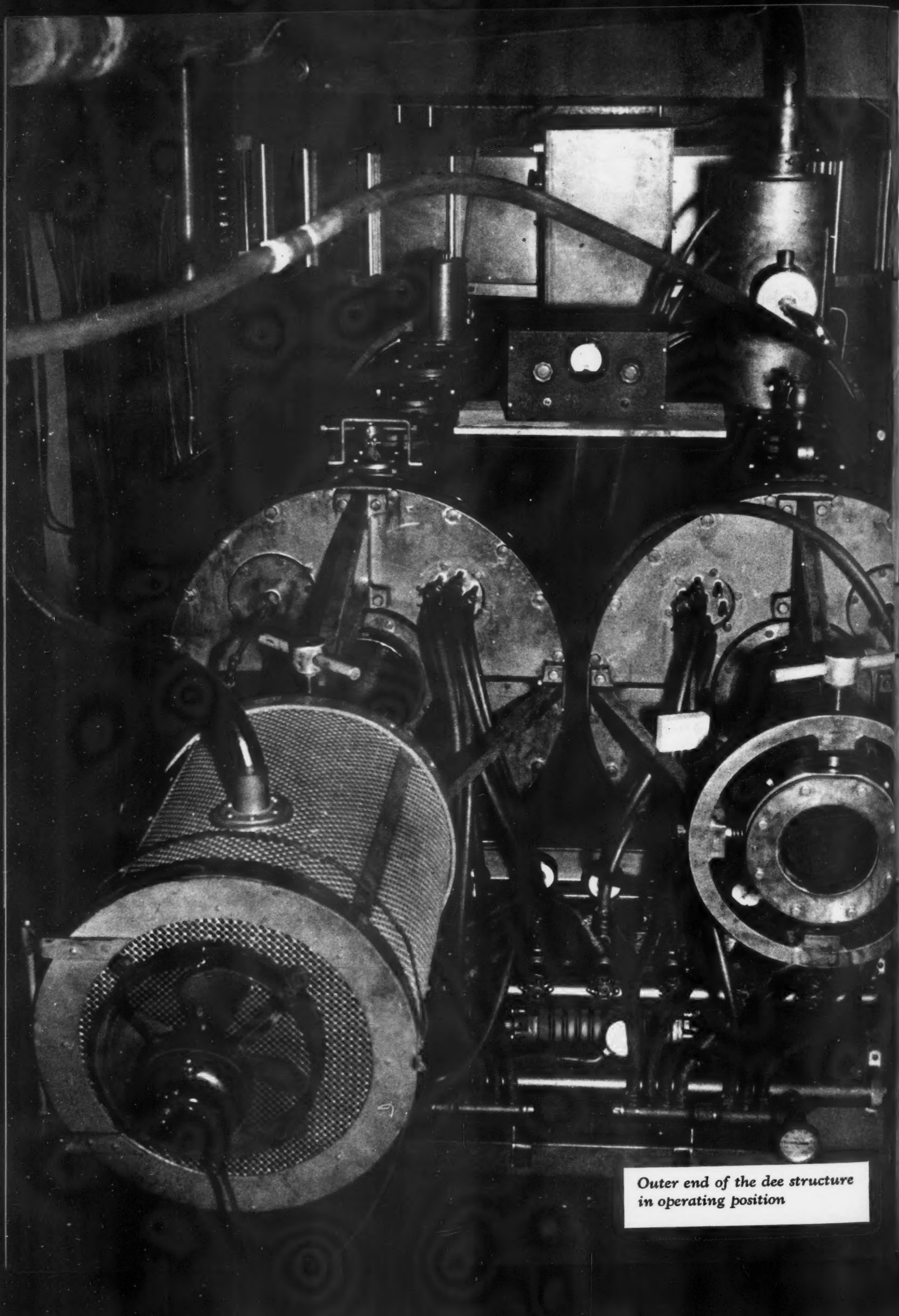
The dee structure before assembly with the magnet

The M. I. T. cyclotron operates at a deuteron energy of 14 MEV, with a final orbit radius of 19″, a frequency of 12 megacycles, and a magnetic field of 16 kilogauss.

How Targets Are Bombarded

Most targets suitable for bombardment in vacua are secured on the end of a probe which places the target so that the last orbit is intercepted. The ions bombarding the target dissipate most of their energy as heat; therefore, the target must be effectively cooled. The target is tilted slightly in an effort to spread the beam, but at the M. I. T. cyclotron two much more effective methods are used.

The first method consists in wiggling the target up



Outer end of the dee structure in operating position

and down in the ion beam so that the beam, the cross section of which is of the order of a few square millimeters, is spread over many times its own area. This is done by the wiggler target holder, a special adaptation of the probe. Target materials are usually silver-soldered on the target head made of soft copper tubing which carries the target cooling water. A flattened portion of the head provides a high velocity water flow and a convenient place to solder the target.

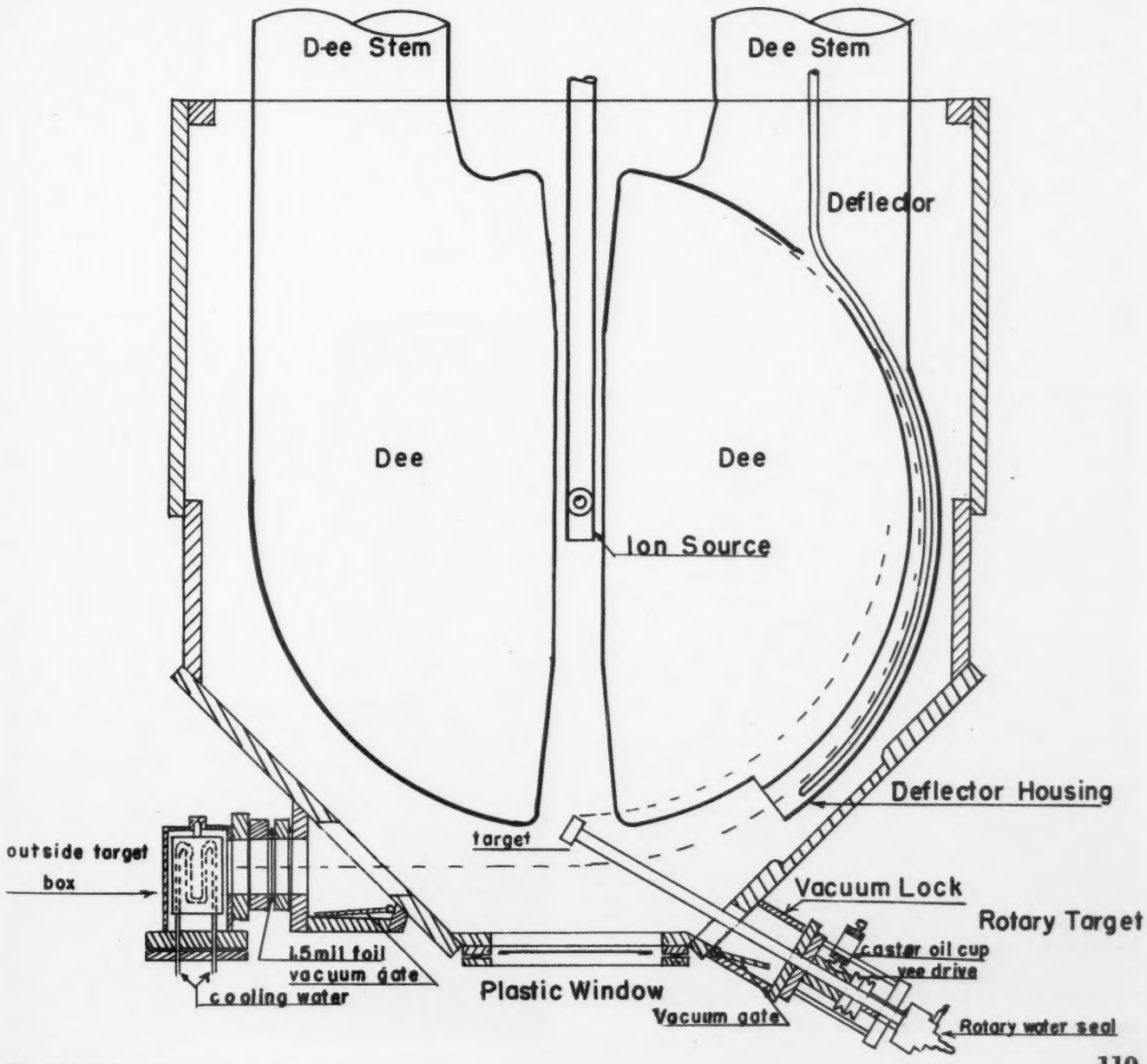
An even more effective arrangement is the rotary type probe. The target is electroplated on a copper cup which is rotated in the ion beam. The cup is on the end of a stainless steel shaft which carries target cooling water. The rotary probe has proved very successful in keeping the target from burning, but the copper cups crack and leak after forty hours or so of operation, since they are under a constant strain from the alternate heating and cooling as they rotate in the beam.

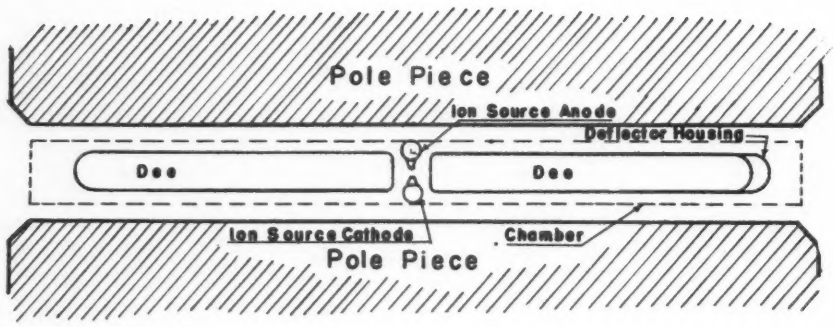
Certain targets cannot be bombarded in vacuum. Instead of letting the target intercept the beam in the dee gap, the beam passes through a slot provided at the place where the beam would strike the dee if it were not intercepted. A long, curved electrode, the deflector, which is maintained at a negative potential of about 50 kilovolts to ground, then pulls the beam out tangentially from its circular path. The ions leave the main vacuum through a very thin duraluminum foil and then bombard the target in an external target chamber. The target material is spread on a water-cooled copper plate which can be tilted to increase the area struck by the beam. Helium at atmospheric pressure is kept in the target chamber to provide additional cooling.

General Construction of the M. I. T. Cyclotron

The magnet of the M. I. T. cyclotron, built in 1938, is cast of Armco magnetic iron. The coils, designed and built by General Electric, are excited by a 40 kilowatt motor-generator set. The magnet develops a uniformly constant magnetic field of up to 18 kilogauss between

Top view of the chamber showing position of dees and ion source. The probe target is the rotary type, the other type being the "wiggler," where the target is wiggled up and down. The system is so interlocked that the probe must be withdrawn and the vacuum gate closed before an outside beam can be run. The trimmer condensers (not shown) are mounted on the two side plates.





Front view of chamber showing position of the dees and ion source with respect to the pole pieces. The chamber lids and the trimmer condensers not shown.

42-inch diameter pole pieces across a five-inch vacuum gap.

The vacuum chamber, located between the pole pieces, houses the dee assemble. It is built of bronze, silver soldered at the joints, with lids of Armco iron plate, which act as extensions of the pole pieces. The side plates of the chamber are removable, target housings and trimmer condensers being mounted on these plates.

The dees are supported on the end of long dee stems of seven-inch diameter copper. These dee stems form the inner conductors of two large, evacuated, co-axial lines, the outer conductors of which are the vacuum jackets for the system and are 24 inches in diameter. Adjustable shields at the far ends of these co-axial lines ground the inner to the outer conductor, thereby forming electrically resonant, one-fourth-wave lines.

The deflector is a chromium-plated, water-cooled copper tube which runs along the outer edge of the right-hand dee. The inside of the deflector housing is also chromium plated to reduce discharges. The intensity and position of the outside beam depend, among other things, on the position of the deflector as well as the voltage which can be applied.

The ion source, located at the center of the chamber, is a capillary type arc in which deuterium gas is ionized. The arc is struck between a tungsten filament and a water-cooled tungsten anode. The deuterium, which leaks into the source at low pressure, must be as free from water vapor and oxygen as possible, as these impurities cause filament lives to be decreased considerably. The filament is mounted on a stem and is changed by withdrawing the stem through a vacuum lock.

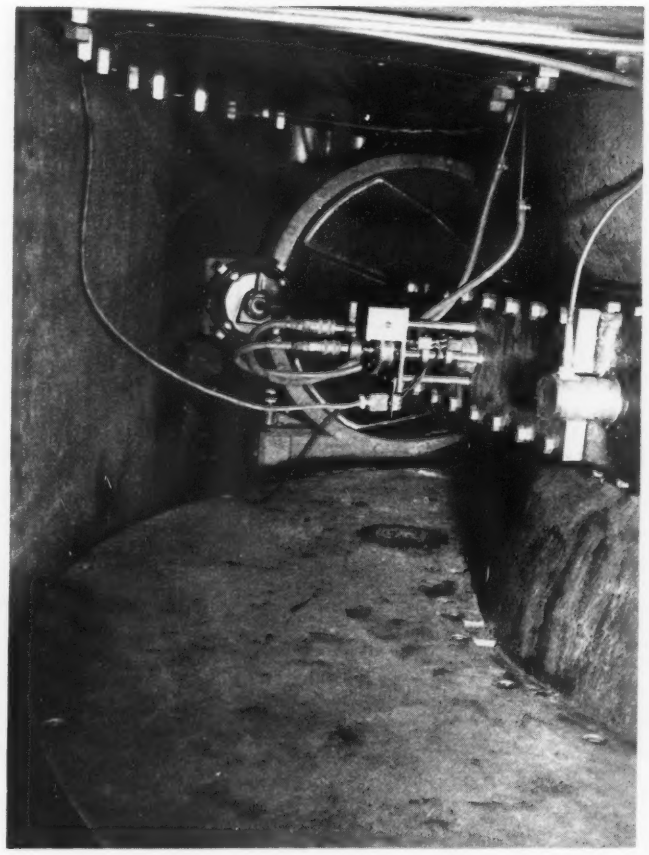
The Accelerating Potential

As was shown in a previous section, the cyclotron for its operation requires the application of high-frequency alternating voltages to the dees. Theoretically, the energy of the ions in the final orbit is independent of the magnitude of the accelerating voltage; if one volt were applied between the dees, the ions would make seven million revolutions to end with an energy of 14 MEV. However, effects enter into the picture which in practice demand that the interelectrode voltages be above a certain value. The enormously long paths involved when successive accelerations are small allow the disruptive effects of collisions of the ions with stray air molecules to become important, and make the focusing requirements more stringent. The electric fields set up are used not only to accelerate the ions, but also to provide forces tending to direct the ions into the central horizontal plane. Thus it is found that the number of ions per unit time reaching the final orbit is a strong function of the accelerating voltage. The maximum voltage obtainable is, of course, limited not only by the power available but also by the dielectric strength of the gaps between dees and chamber.

It is found that radio-frequency voltages of the order of 100 kilovolts between dees will produce a beam intensity of about 250 microamperes, above which current most targets will burn away. The maximum beam intensity thus far achieved by the M. I. T. cyclotron is one milliampere, or 14 kilowatts of high-speed ions, a power level which burned through the water-cooled probe in about ten seconds.

The radio-frequency power source for the M. I. T. cyclotron was designed to fill the special needs required with maximum efficiency and simplicity. It consists simply of a push-pull, resonant-line, neutralized 100 kilowatt, self-excited oscillator, feeding its power through a loop-coupled transmission line to the resonant dee system. Excitation is fed back from the cyclotron in such a way that when a spark-over occurs within the chamber the excitation is automatically removed, protecting both the cyclotron and the oscillator from damage. Of the several tuned circuits involved, that of the dee system is by far the sharpest, having an operating Q of over 3,000, while the others are broad enough to follow small frequency changes in the dees without requiring retuning.

(*Continued on page 142*)



Interior end of the dee assembly showing the pole pieces of the magnet to the right

Wright Brothers Wind Tunnel

By MARVIN W. SWEENEY, 2-47

CONSTRUCTION on the M. I. T. Wright Brothers Wind Tunnel, started in 1938, was completed late in 1939, just in time to aid industry with war contracts with France and England. Before the United States entered the war considerable work was done on the Martin 187 for England.

During our participation in the war only military airplanes were tested. Test work was done on practically every military airplane built in the United States, although most of the work was done on planes such as the B-26, P-55, C-47, Martin Mars, SB2-C, P-33, and the P-36. Work was done for every airplane company in the country except Douglas, North American, and Northrup. Testing could not be done for these companies because of the full schedule.

Considerable research and development was done on internal flow; *i.e.*, ducting, cowling, and induction systems for cooling fans.

A means for measuring hinge moments was developed. By knowing the angle of attack of the control surface and the angle of deflection required for various manocurves it is now possible to compute the force required on the controls to execute them.

In 1940 new equipment was installed to permit testing models with power-driven propellers. The M. I. T. Tunnel was one of the first in the country to do power-testing. This was a very important development, as the results obtained from testing a model with power on are very different from results obtained with power off. A tremendous amount of power testing has been done in the Tunnel — and done extremely well.

It had one of the early installations for testing models of jet planes. Air was pumped from the 150 hp Tunnel compressor through the plane to simulate a jet. With this installation very comprehensive test data were obtained.

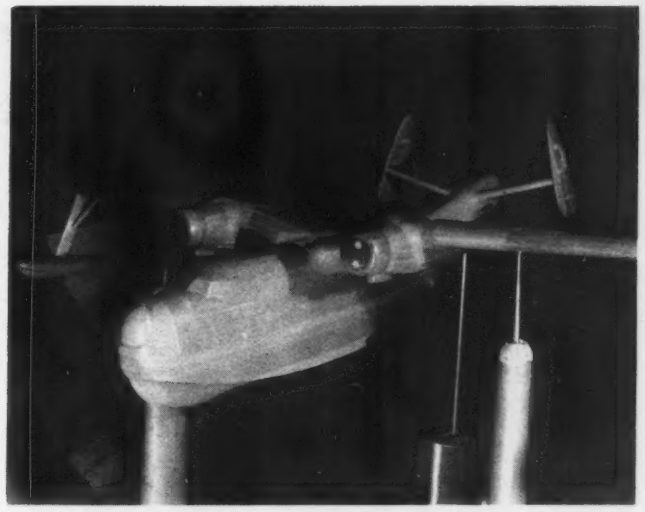
Because testing was done only on military airplanes the Government never took it over. It was under the direction of the Institute throughout the war, and has been in operation day and night for quite some time.

Professor J. R. Markham, director of the Tunnel, was ably assisted by Professors S. Ober, J. Bicknell, and others.

The Tunnel is of the closed-return type with a 10 by 7½ ft. elliptical test section. At atmospheric pressure the air-speed is 250 mph, but it can be operated at pressures of 4 atm. or ¼ atm. It has a center line distance of 196 ft. 2 in.

The construction is of arc-welded steel plates, varying in thickness from ½ in. to ¾ in. With the addition of external stiffening rings the Tunnel was made adequately strong for the pressures encountered.

By making the test section elliptical it is possible to test models with a larger wing span than could be tested in a circular cross-section of the same area. The bottom of the ellipse is flat to simplify balance and support installations. The entire test section is made of wood and surrounded by a metal shell which extends from the front of the nozzle to the first corner. Thus the test section and the surrounding shell are at the same static pressure. This was done to simplify the transmitting of forces from the model to the measuring system and to eliminate the airtight joints that would be needed between the supporting members and the test section. Moreover, by making the test section of wood, and the airtight joints on the outer shell, it is possible to change the shape of the test section and make possible a variety of ways to suspend the model.



A Martin PBM in the test chamber

The rest of the Tunnel is of circular cross-section. The transition from the elliptical section to the circular is made in the diffuser at the first corner. The transition

The Wright Tunnel as it was originally built

The six-bladed variable pitch propeller in the Wright Tunnel

back to the ellipse is made at the entrance to the test section. The cross-section area increases from the test section on until it reaches a maximum diameter of 19 ft. 4 in. at the third corner. The diameter then remains constant until the nozzle of the test section is reached. (The corners are numbered counterclockwise in the direction of flow starting with the corner at the end of the test section.)

The propeller and motor are located just beyond the second corner. At this point the driving motor is mounted on the only heavy anchorage for the Tunnel. With this type of mounting it is possible to use a clearance between the blade tips and walls of ⅛ to ¼ in. The diameter of the tunnel is constant at 13 ft. in front and behind the motor. Because of this the velocity of the air is low enough so that the tip speed of the propeller is below the velocity of sound.

The motor resistance is reduced by a streamline fairing and five guide vanes are used to remove the rotation of the air induced by the rotating fan. Two of these vanes are used to support the motor and help cool the air.

The driving motor is an induction motor rated at 2,000 hp. at 2,200 volts. To make possible a greater range of tunnel velocities it can be operated at four different speeds: 1175, 880, 585, and 440 rpm. Because the Tunnel temperature may get as high as 160° F.,the cooling problems for such a motor are great. Cooling air is supplied to the motor through the hollow motor supports. The cooling system consists of a 40 hp. centrifugal blower, a large air filter, and a small heating unit and blower to prevent the condensation of moisture in the motor when it is not running.

The motor drives a 13 ft. variable-pitch wooden propeller that has six blades. The blades are mounted in a 40 in. diameter steel casting. A ½ hp. three phase motor mounted in line with the propeller changes the pitch and increases the number of tunnel velocities possible.

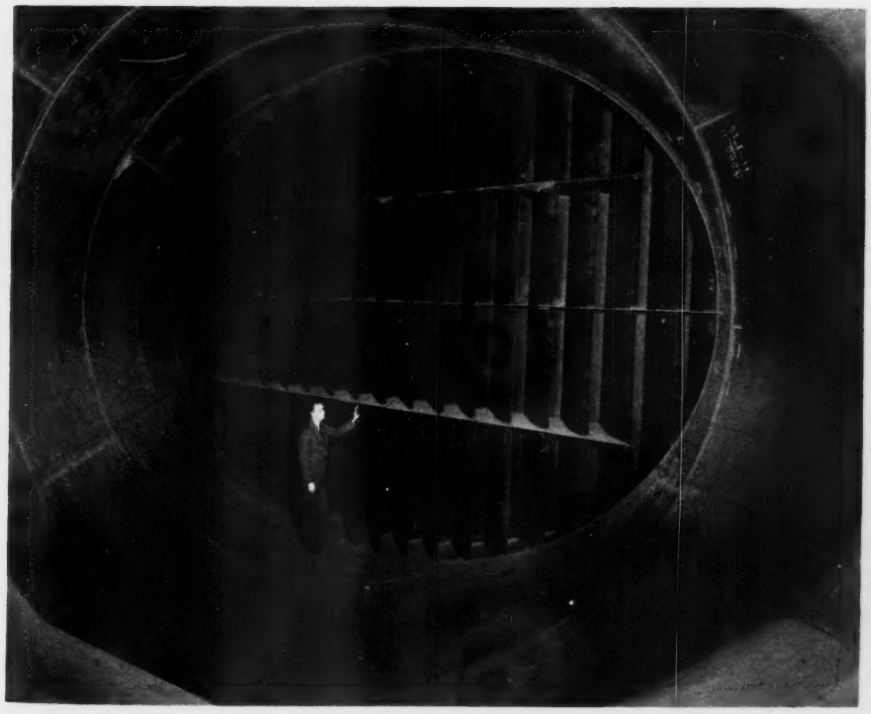
Professor Markham, Director of the Tunnel

Because of the tremendous heat generated when the Tunnel is operating at maximum speed (all of the motor output is converted to heat at this velocity), some means is needed to remove it. By pumping water from the Charles River and covering the entire shell with a water film it is possible to withdraw this heat from the Tunnel. The cooling water is then drained back into the river.

It requires about 2½ hours to compress the 32,000 cu. ft. of air in the Tunnel to 4 atm., and somewhat less time to exhaust it to ¼ atm. The compression-reduction system consists of a 150 hp. induction motor which drives a water seal compressor. The system is connected to the Tunnel by a system of valves that permits the intake of the compressor to be opened to the Tunnel or outside air. 260 mph is the maximum velocity attainable at rated power and normal density. At 3.5 atm. the measured velocity at rated power was 145 mph., although a speed of 396 mph. has been attained at 0.23 atm.

There can be little doubt that with the Wright Brothers Wind Tunnel and the fine Department of Aeronautical Engineering at the Institute, M. I. T.'s contribution to aerodynamic research will be greatly advanced in the future.

Flow-correcting vanes installed at the corners of the Tunnel



The Draper Computing Gun Sight

ON October 26, 1942, the mighty battleship *South Dakota* shot down thirty-two Japanese aircraft which were determined to sink her and the carrier she was protecting. Students of naval warfare and laymen alike were amazed that anti-aircraft from a surface ship should have such deadly results on attacking airplanes. The reason for these results and the subsequent achievements attained by anti-aircraft batteries on virtually all United States naval vessels is the use of the Draper gun sight, which introduces the proper lead angle in firing at moving targets. This is one of a series of devices employing gyroscopic principles which were invented and built by Professor C. Stark Draper and his associates in the Instruments Laboratory of the Department of Aeronautical Engineering at M. I. T.

The story behind the sight which the Navy calls the Mark 14 Gyro Gun Sight, in such detail as security restrictions even now will permit, was contained in the August, 1945, issue of *Sperryscope*, publication of the Sperry Corporation. The Navy had recognized quite some time before Pearl Harbor that there was a pressing need for some radical improvement in gun sights for use against aircraft. None of the sighting and aiming methods then in use could swing the guns nor aim them accurately enough in a very short time to provide really effective resistance against determined attacks by aircraft. Something had to be done quickly. Dr. C. Stark Draper of M. I. T., an authority on gyroscopics, was approached, and the whole problem was laid before him. Fortunately, for several years prior to Pearl Harbor, M. I. T. and the Sperry Gyroscope Company had been interested in the development of a "rate" gyroscope. It was thought that this could be the basis for the development of a new and revolutionary gyroscopic gun sight.

Dr. Draper worked out the mathematical conditions required of the mechanism during the summer of 1940. Among other things, these conditions called for a gyroscopic mounting that would be rugged but almost frictionless. Springs six one-thousandths of an inch thick were needed, as was a thermostat accurate within one degree in a range from 20° F. to 180° F. A special high-strength metal had to be developed for the precision springs which constituted a very important part of the mechanism. Moreover, gyroscopes are used to compute the angular rates of the target, and these scopes had to be spun by air to attain the required means of controlling the speed of the rotors for accurate calibration. However, sea air could not be allowed to enter into the delicate parts of the computing mechanism; hence a closed air system was required, which in turn meant the development of a new type air-pump. A special system of drying had to be devised to prevent moisture from condensing on the optical parts in the sights. These problems are merely illustrative of the hundreds of difficulties which had to be overcome before an effective gun sight could be produced.

Professor Draper

In the operation of the gun sight, the operator has merely to follow the target, always keeping the image of a circle of light which appears to be suspended in the sky superimposed upon the target. The instrument itself automatically makes all the necessary computations and sets the guns on the target. The roll and pitch of the ship, of course, has no effect on the instrument since the operator must always sight on the target.

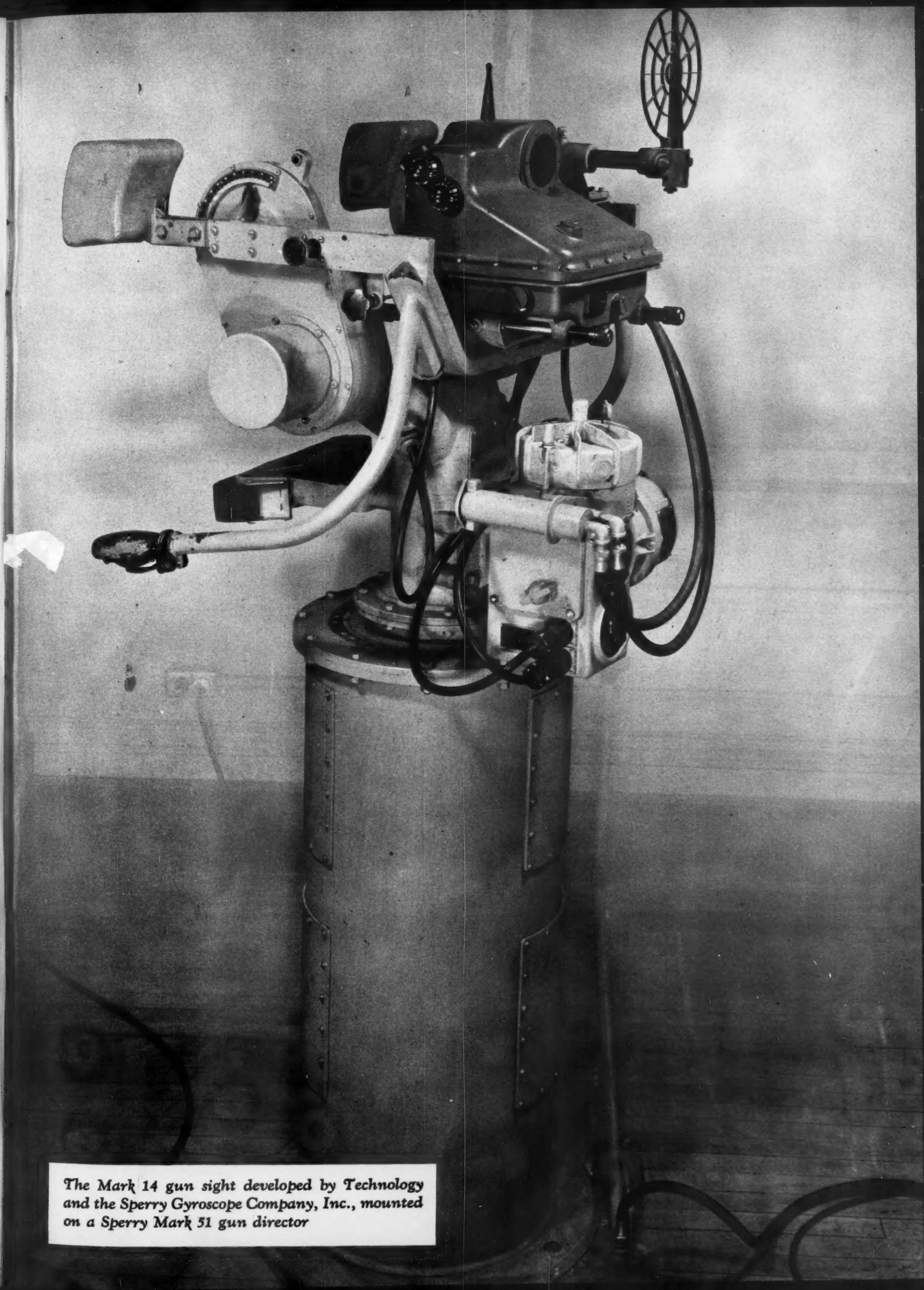
The new sight enables the gunner to devote his entire energy to "tracking" his target, thus freeing him of tasks requiring judgment. Consequently, the problem of training personnel for anti-aircraft gunnery has become vastly simpler.

This Mark 14 gyro sight was first used with rapid firing 20 mm anti-aircraft guns. Later it found use in conjunction with the Mark 51 gun director with 40 mm guns, and the combination proved quite effective as remote control firing apparatus.

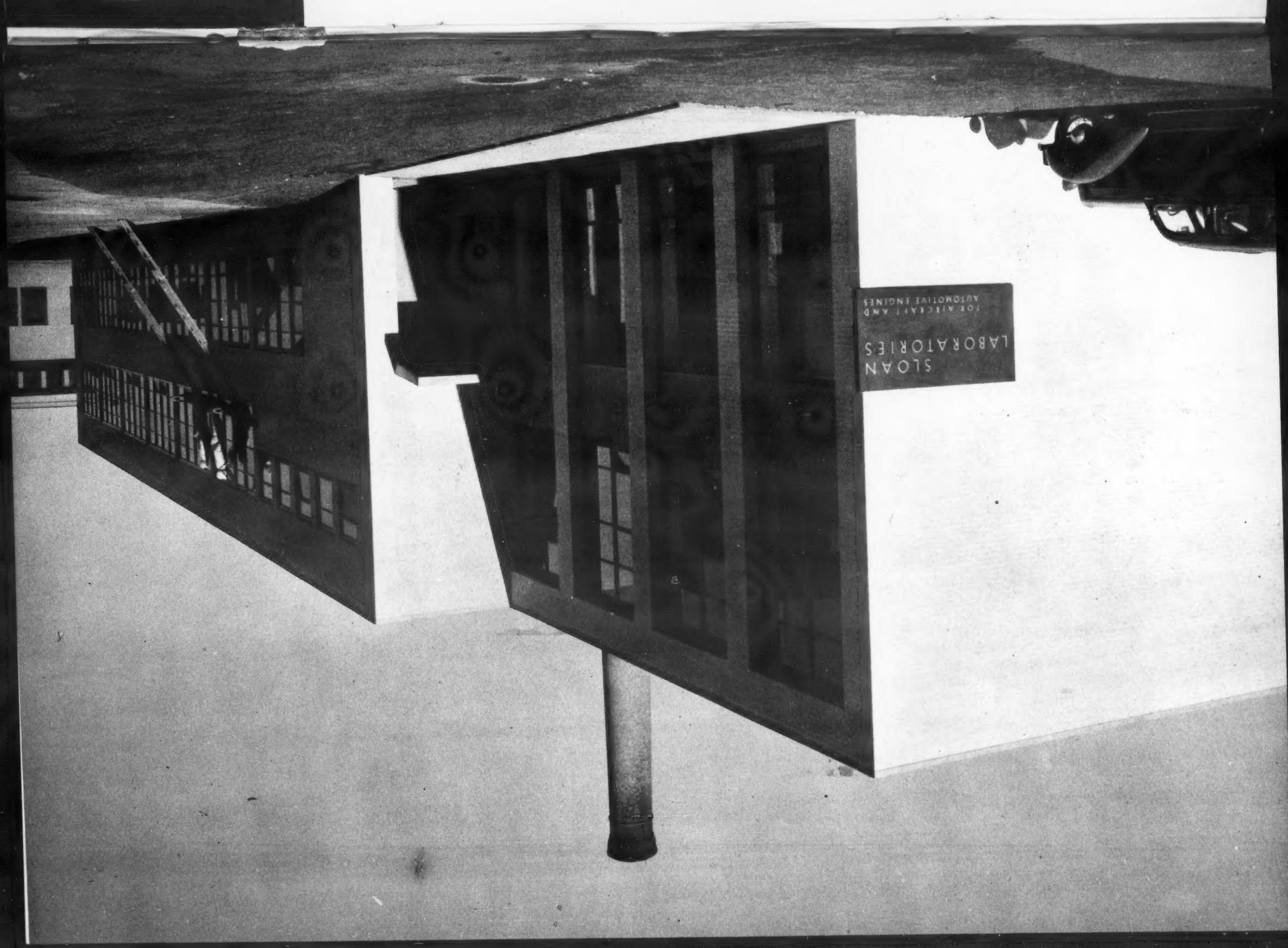
"The M. I. T. Instruments Laboratory has long been concerned with advanced fire control research for both services; the program undertaken during the war, which will continue in part until certain specific tasks are completed, provides the basis for a fundamental attack on peacetime problems of control and instrumentation. The prime objective of this laboratory is the education of students on an advanced level in the philosophy and techniques of instrumentation, and the specific research projects undertaken for Government and industry by the group have led to advances in the art which will be reflected in the educational program."*

—FRANK J. HEGER, 2–47.

*Dr. Compton's report on the Institute's war activities.



The Mark 14 gun sight developed by Technology and the Sperry Gyroscope Company, Inc., mounted on a Sperry Mark 51 gun director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SLOAN LABORATORIES

FOR AIRCRAFT AND AUTOMOTIVE ENGINES

THE Sloan Automotive Laboratories, under the direction of Professor C. F. Taylor, have played an important role in M. I. T.'s war program.

In addition to its regular activities of handling courses for graduate and undergraduate students at the Institute, the Laboratory has trained over a thousand Aviation Volunteer Specialist (AVS) naval reserve officers, providing sixteen weeks courses in aeronautical engineering and aircraft engines. These men have stood well their battle tests in maintenance work and field service repairing all over the world.

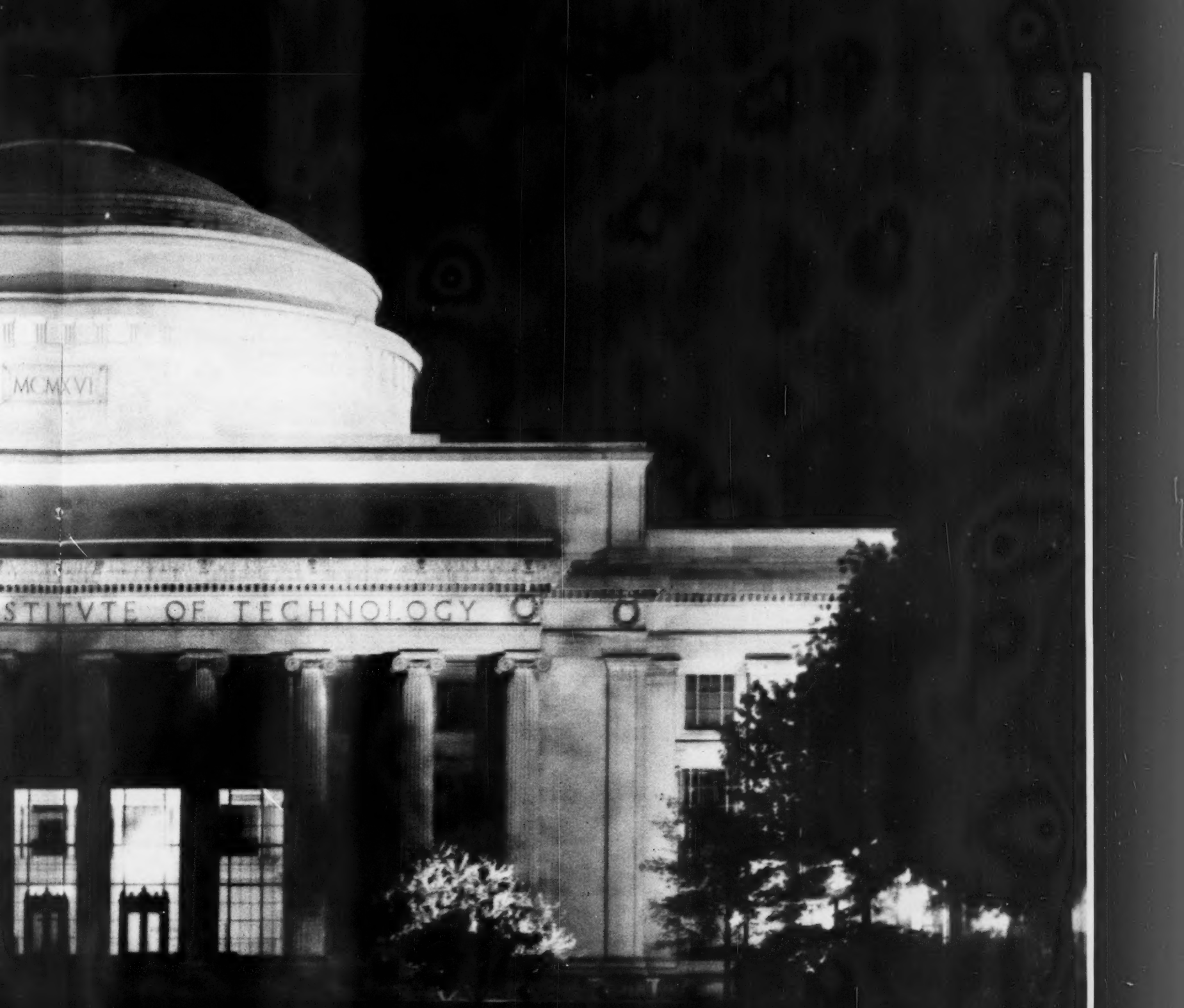
The Sloan Automotive Laboratories have also conducted fundamental research projects for the Government, the National Advisory Committee on Aviation (NACA), and numerous commercial companies. These projects are of such a secret nature that they may not even yet be disclosed.

— GUIDO J. FRASSINELLI, 2–48

ABOVE
A drafting room in the Sloan Laboratories

RIGHT:
A corner of the Laboratories

With the war over, the lights on M. I. T.'s great dome are again turned on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M. I. T. AT WAR— THE SERVICE RECORD

When we conceived the idea, some months ago, of publishing this one issue dedicated specifically to M. I. T.'s service record, the difficulties which we were to encounter had not as yet begun to harass the waking moments of our more conscientious staff members. But before the project had been pushed very far, however, the basic problem of procuring partially restricted material with a relatively inexperienced staff began to be realized.

That we were able to present such a comprehensive over-all picture of the war activities here at Tech is due partly to the energy of our staff members, both old and new, and partly to the very helpful cooperation of the directors and workers of the research projects themselves, without whose assistance the preparation of some of this material might well have been impossible. The staff would like to thank here once again those people who worked with us on this issue.

Despite the quantity of information presented here, however, it should be thoroughly understood that a great amount of the work accomplished here at the Institute during the war is yet under the classification of RESTRICTED. As in the months to come the bans are gradually lifted, we will be able to present more and more of this remarkable story. And it should be emphasized that "the best is yet to come!"

In keeping with its proclaimed policies, *T. E. N.* will continue to present as much of this information as possible to its readers, together with news of developments in the various fields of engineering. Meanwhile, several changes in form and presentation have been instituted in this issue and the next which are designed to improve the magazine.

The theme of this issue — M. I. T. at War — is really the background music for many a headlined victory about which we have read these past four years. The role of Science in warfare has loomed ever larger in modern history until today we may say that technological superiority is the prime factor which determines the fate of nations. No longer do the laurels go to the brave alone: courageous hearts will count for but little if we must ever face a future deluge of rocket-propelled atom bombs.

The concentrated application of scientific research to the ways of warfare has, in the past five years alone, produced a terrifying array of destructive weapons. The development of magnetic mines, rocket guns and bombs, devastating incendiaries and flame weapons, to mention but a few, is rivaled only by the perfection, behind the scenes, of the deadly poison gases and other lethal instruments which were not used only because we had more of them than did the enemy. And the final dramatic release of the ultimate forces of atomic power has given the world one shattering glimpse of the suicidal direction of its blunderings.

M. I. T. has played its great part in the destruction of our enemies; but its students have been trained to preserve and create. Now that its brains and resources are turned once again to the work of peace, we may review the record. But we must not forget the cost. Let the service flags of the Institute and the Nation wave victoriously overhead, but let their long lines of golden stars remind us that the war won by Science was paid for with blood — and tears.

S. L. S.

"More farm life for me!"

New developments, offering advantages of speed and economy in construction, are being fully used in our program for extending and improving farm telephone service.

Among these are mechanical pole-hole diggers and plows for burying wire underground. Sturdier steel wire that permits longer spans will require fewer poles.

And we are experimenting with "power line carrier" to provide telephone service over rural electric lines. Radio, too, is being studied for use in connecting more isolated sections with telephone exchanges.

Providing more and better rural telephone service is part of the Bell System plans for constantly improving nationwide communications service.

BELL TELEPHONE SYSTEM

Dr. Lee A. DuBridge, Radiation Laboratory Director

RADIATION LABORATORY

(*Continued from page 111*)

trative problems of running a large establishment had to be met. Unable to recruit enough skilled help, the Laboratory broke down its operations and hired hundreds of unskilled workers. More hundreds of women and girls were employed, the number eventually reaching over fourteen hundred, including seventy-five women staff-members who were physicists, technical experts or administrative personnel. Most of the women were technicians, draftswomen, or machinists; and an entire trade-school setup was created within the Laboratory to train them. The equipment built by trainees during their training was simple but urgently needed laboratory apparatus.

During 1943, a Laboratory branch was established in England, to provide closer liaison with the British on an important radar set using both British and American parts. This British branch was soon closely linked with the United States Army in England, and later on the Continent, largely through the efforts of other Radiation Laboratory personnel attached to top commanders as representatives of the Office of the Secretary of War, to advise on the operational use of radar.

Thus began a period when Radiation Laboratory scientists donned uniforms as civilian advisers in the active theatres. Eventually the British branch of the Radiation Laboratory reached an enrollment of one hundred and twenty-five, and its specialists could be found not only in every important headquarters, but also with troops in the field wherever new radar uses were being worked out.

This infiltration of military ranks by civilian scientific advisers proved so fruitful that General Patton said, "This is the way that wars not only can, but should be, run." Radiation Laboratory products, and Radiation Laboratory specialists, played important parts in the North African campaign, the fighting in Sicily and Italy, the Normandy invasion, the breakthrough in France, and the strategic bombing campaigns from 1943 on.

Early Warning

Standing as a bulwark of defense against the approach of enemy planes through darkness, rain or fog along the entire western front from D day until V-E day was a Radiation Laboratory product recognized as one of the most indispensable early-warning radar systems of the war.

And while the original functions of this massive but spectacular microwave set is warning against enemy planes, its extra-long range and almost uncanny knack for discerning between closely bunched targets (commonly referred to as high resolution) have enabled it to perform a great many other tasks that no other radar could do.

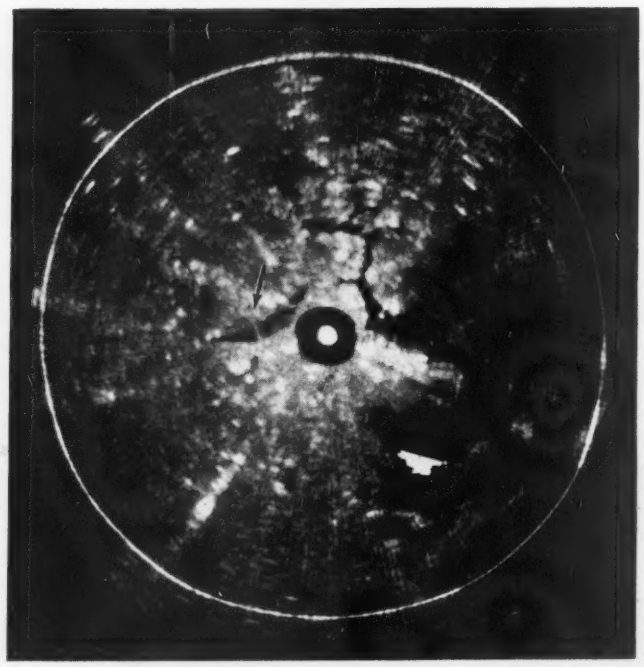
So indispensable were the several of these systems on the western front that the Army Air Forces units to which they were attached gave them only forty-eight hours "off the air" for a hundred-mile move. And there were a great many moves to be made, what with the front changing rapidly at times.

Constructed by Radiation Laboratory before the invasion of Normandy, the first of these sets were sited along the coast of England for warning against German planes, direction of Allied fighters and bombers, and spotting buzz-bombs. One of them hit the Normandy beachhead a few days after D-day and later several more followed the front lines rather closely. This, while permitting maximum coverage of active areas by radar, often brought the systems too close to the enemy for comfort. And although none of the sets were destroyed by the enemy, one of them in Belgium evaded in the nick of time the Germans forging ahead during the Battle of the Bulge.

Radiation Laboratory personnel who helped design and construct these sets donned uniforms and followed them into combat areas to make certain they were always operating "at the peak."

Whenever our lines moved forward enough to neces-

(*Continued on page 134*)



Radar-map of Boston. The arrow indicates the M.I.T. Radiation Lab

BUDD *INTRODUCES*

NEW SLEEPING CAR EQUIPMENT OF UN-EXAMPLED CONVENIENCE AND LUXURY

Rail travel in the post-war world will have vastly improved sleeping car accommodations. Each passenger will have privacy and seclusion, and comforts of a new kind. To provide accommodations like these, Budd has designed sleeping cars with four types of private rooms. Here is one of them:

THE MASTER ROOM

This is a most luxurious apartment. Two Double Bedrooms are arranged en suite with folding partition which has a communicating door. By day, the Master Room has seats for six. At night, it becomes two rooms—each with two beds, an enclosed toilet, lavatory, shower and full-length wardrobe. The arrangement is ideal for families traveling with children.

In the Master Room, and in the Double Bedroom, Cabin and Budgette, Budd continues a policy of bringing to the railroads and traveling public the most modern ideas in passenger equipment engineering.

EDWARD G. BUDD MANUFACTURING COMPANY Budd

RADIATION LABORATORY

(*Continued from page 132*)

sitate moving the radar, a large fleet of trucks carrying the antenna, indicators, maintenance gear, diesel and gasoline power units, portable houses for operations rooms, kitchens for the large crew and innumerable other items had to pack up and shove off. None got much sleep during this forty-eight-hour period, but somehow, despite horrible roads and other impediments, the job was always accomplished.

Meanwhile, several of these early warning systems went to United States-held islands in the Pacific and performed tasks similar to those in Europe — furnishing information on enemy planes approaching many, many miles away, helping lost Allied fighters and bombers find their way home, and so on.

And while the story of the set in the Pacific ends formally on V-J day, it is obvious that radar's work never will be done. In many locations all over the world the system will be found with other supporting sets which obtain height and other data for the early-warning gear to control and direct aircraft.

Microwaves are so short that they can not be carried by ordinary wires and antennas. Instead, they are carried inside a rectangular pipe or waveguide (often termed plumbing) from a powerful magnetron to the antenna. Here they are focused by parabolic reflectors (just as light waves in a searchlight) and are concentrated in a very sharp beam.

The shape and size of the antenna makes the beam very narrow, giving the very high angular resolution. A large modulator furnishes the transmitter with pulses or bursts of power — pulses which are measured not in seconds, but in terms of millionths of seconds. Any plane within the range of these pulses will reflect them, much diminished, to the antenna and waveguide, where they pass into the receiver, where they are greatly amplified.

The receiver converts the pulses into "video" signals, which can be seen in the indicator on a cathode ray oscilloscope as bright spots of light. Range can be obtained by measuring the time required for the pulse to echo back to the receiver, just as a sound locator might measure the time it takes a sound echo to reach a mountain and return.

This time delay is converted by the circuits of the indicator to distance along the face of the scope and is read by the operator in terms of miles or yards.

So many targets are "seen" by the radar that a large number of scopes are needed to enable a sufficient number of persons to observe and record all that is happening. Scope operators, in fact, must concentrate to such an extent that they tire quickly and must be relieved frequently.

A scope showing a complete map centered at the radar and another showing an expanded section of a map are located in the operations or "ops" room, where operators relay information by telephone to a group of plotters at a large vertical plotting board.

On this transparent board, plotting is done from the rear so that plotters will not obstruct the view even for an instant. Watching the board from the front is a group of controllers and other officers assigned to determine what action should be taken as situations develop.

Meanwhile, planes are identified with IFF (identification friend or foe) equipment and radar beacons, and the planes that prove to be friendly are directed by VHF (very high frequency) radiotelephone. The

(*Continued on page 136*)

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Dairies Everywhere Like FRICK Refrigeration

Because it sets the standards of dependability, convenience, and overall economy. Whether for cooling milk, freezing ice cream, keeping storage rooms cold, refrigerating trucks, making ice, or conditioning air, you'll find Frick equipment the choice of leading dairies throughout the country. Let us quote on YOUR cooling needs: write, wire or phone

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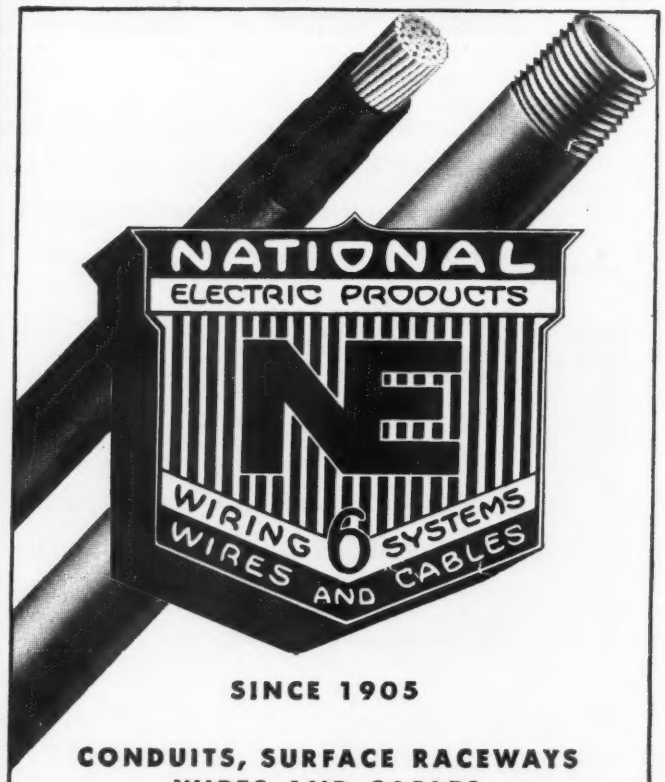

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National Electric
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MAGNESIUM

THE LIGHTWEIGHT METAL WITH A MISSION

Destined to lighten labor

and free moving machines from deadly weight

Magnesium is the metal that makes the front pages of today's newspapers because it is news. So light a metal—one-quarter the weight of steel and a full third lighter than aluminum—will long continue to be news because it is the Metal of Motion whose mission is to free the world from the hampering and fatiguing effects of deadweight. Now that it has fulfilled its wartime duties it is readily available to all industry and to ease labor wherever tools are used. Dow is the pioneer producer of this metal that is destined to change our lives, recovering it from ocean water at the great Texas plants and also from Michigan brine. Dow is likewise the developer of Dowmetal Magnesium Alloys and operates foundries and plants for their fabrication. These achievements with magnesium are noteworthy examples of Dow's capacity to advance industry through outstanding developments in chemical engineering.

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DOW

CHEMICALS
INDISPENSABLE TO INDUSTRY

RADIATION LABORATORY

(*Continued from page 134*)

operations room also serves as a filter room for reporting to radar warning networks.

Mobile Microwave Anti-Aircraft Radar

The Radiation Laboratory started the development of a mobile radar equipment that would automatically track enemy aircraft and aim anti-aircraft guns in January, 1941. The first laboratory model of this radar system that incorporated the most advanced ideas of automatic fire control was operating by May, 1941, on a roof of M. I. T. A small airplane, piloted by a member of the Laboratory, flew daily above the buildings of the Institute and was tracked by the radar.

Another model, known as Experimental Truck No. 1 (XT-1), was started in July, 1941, at the request of the Army. It was first demonstrated to Army personnel on December 1, 1941, at a Signal Corps Laboratory in New Jersey. The remarkable accuracy of this device caused the Army to call for thorough-going tests with anti-aircraft guns, at a site where robot planes and sleeves could be fired at in a simulation of actual warfare. These later tests with XT-1 were completed in April of 1942, and the equipment was standardized for production. The General Electric Company and Westinghouse Electric and Manufacturing Company were given letters of intent for production. Members of the Radiation Laboratory were detailed to work closely with the two prime contractors in the transfer of the design into production units.

E. G. Bowen, of the British scientific mission, L. A. DuBridge, and I. I. Rabi examine an American-made magnetron

The "Baptism of Fire" for Nazi aircraft occurred at the Anzio beachhead in Italy in February, 1944. The Germans had been sending many night-bombing raids over the beachhead in an almost successful attempt to exterminate it. The first set, coupled with four anti-aircraft guns, opened fire in complete darkness on twelve unsuspecting German planes. Seven of the twelve planes came down in flames, a toll which had never before been accomplished by the same amount of radar-armed gunfire. German air raids over the beachhead stopped immediately, and it was almost a week before a single German plane returned to feel out the defenses. This aircraft failed to return to its base.

During the critical period of introduction of the set in Italy, a Radiation Laboratory man assisted the anti-aircraft troops. He was but one of the many scientists — members of this laboratory — who have spent months in far corners of the world.

In the feverish months of activity preceding the invasion of Normandy on June 6, 1944, many sets with their anti-aircraft batteries were deployed in England to protect the huge stores of equipment based on that island. Attacks of a new German weapon, the buzz-bomb, were expected momentarily, and from February, 1944, special anti-aircraft batteries were set up to defend London from them. Once again scientists from this laboratory were on hand. Under the guidance of these uniformed civilians, specialized training courses were quickly organized for Army radar operators and maintenance men.

On D day, many radar sets with anti-aircraft batteries were landed among the first waves of the equipment to go ashore. On their first night ashore these units, which had been set up during the day, defended the beachhead from raids of hostile aircraft. Their defense was so spectacular and successful that for several months not even friendly aircraft were permitted over the beachhead during the hours of darkness. Any aircraft which approached was immediately fired upon by these radar-controlled heavy anti-aircraft guns. The total number of German aircraft destroyed was so great that the losses were credited with decreasing the raids to sporadic sorties.

Shortly after the invasion of France, the Germans began to use the buzz-bombs, or "Divers," in an attempt to obliterate London and many of the major cities in England. Immediately, large numbers of radars with anti-aircraft guns were deployed on the coast of England to intercept these missiles. Because of its small size and high speed, the buzz-bomb was a difficult target. Radiation Laboratory specialists, traveling from one anti-aircraft battery to another, helped keep equipment at topnotch performance. This radar equipment played a major role in directing anti-aircraft fire so accurately that more than ninety per cent of the buzz-bombs failed to get through the defenses.

Whenever and wherever a difficult anti-aircraft problem arose, M. I. T.'s scientists-in-uniform were available—in Africa, England, the continent of Europe, and throughout the Pacific. When a modification of the set was needed for a special purpose, these men, backed by the main Laboratory at M. I. T., were able to provide it ahead of schedule.

How this radar works: The pulses of radar energy are beamed to the target aircraft and are reflected from it, returning to the radar in about one hundred millionths of a second when the plane is ten miles away. The radar receives these pulses, displays them for the range operator, and sends them on to a "Tracking Unit." The tracking unit performs the vital job of keeping the radar correctly pointed. The vehicle in which the equipment is mounted weighs a total of almost ten tons and houses three operators — one of which searches for hostile aircraft on the PPI display tube. When an aircraft's echo is received, a second operator identifies it as a friendly or enemy aircraft with a special IFF

(*Continued on page 138*)

Nothing Rolls Like a Ball . . .

. . . and that fundamental fact has just struck the piano player!

Machine designers, too, have been impressed by that fact. A ball has no ends, needs no artificially fixed axis of rotation. It is nature's favorite, strongest form.

Hence the *ball* bearing. It carries the loads on free-rolling steel balls. It is just *naturally* adapted to our new world of high speeds, heavier loads and ever greater precision.

This is proved by New Departure Ball Bearings in hundreds of millions of applications on land, at sea, in the air—and in every corner of the world.

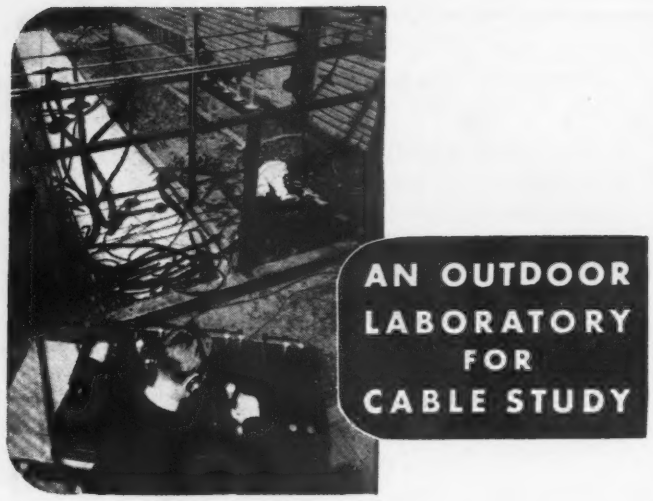
The engineering experience and meticulous manufacturing methods of New Departure, world's largest maker of ball bearings, can be of great advantage to you.

There is more for you in New Departure Ball Bearings than steel and precision. Advanced engineering and a desire to serve are tangible plus values.

NEW DEPARTURE
BALL BEARINGS

3387

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONN. • Branches in DETROIT • CHICAGO • LOS ANGELES and Other Principal Cities



Nothing is guessed at, nothing is taken for granted by the engineers in charge of Okonite's cable proving ground. Buried in various types of chemically different and highly corrosive earth, pulled into conduit or installed overhead, electrical cables are tested under controlled conditions of temperature, voltage and loading conditions duplicating those of actual operation.

In use since 1936, carefully-recorded tests made in this "outdoor laboratory" have disclosed valuable trends. As facts accumulate, Okonite engineers apply their findings to the improvement of their electrical wires and cables. The Okonite Company, Passaic, N. J.

OKONITE
4289 Insulated wires and cables

RADIATION LABORATORY

(*Continued from page 136*)

attachment mounted in the trailer. When the aircraft reaches the range at which the guns may fire, the equipment is thrown over to automatic tracking and a third operator takes control. This operator continuously checks the range from the radar to the aircraft, and in so doing furnishes the information automatically to the gun predictor. The predictor is a device which receives the accurate target position information of the radar and transforms it into a form which is usable by the anti-aircraft guns.

In a complete blind firing operation, the aircraft is never seen or visually identified by any person on the ground. The radar, with one operator at the controls, automatically provides data to the predictor; and the guns can be driven from this predictor entirely without other assistance.

Bombing Through Overcast

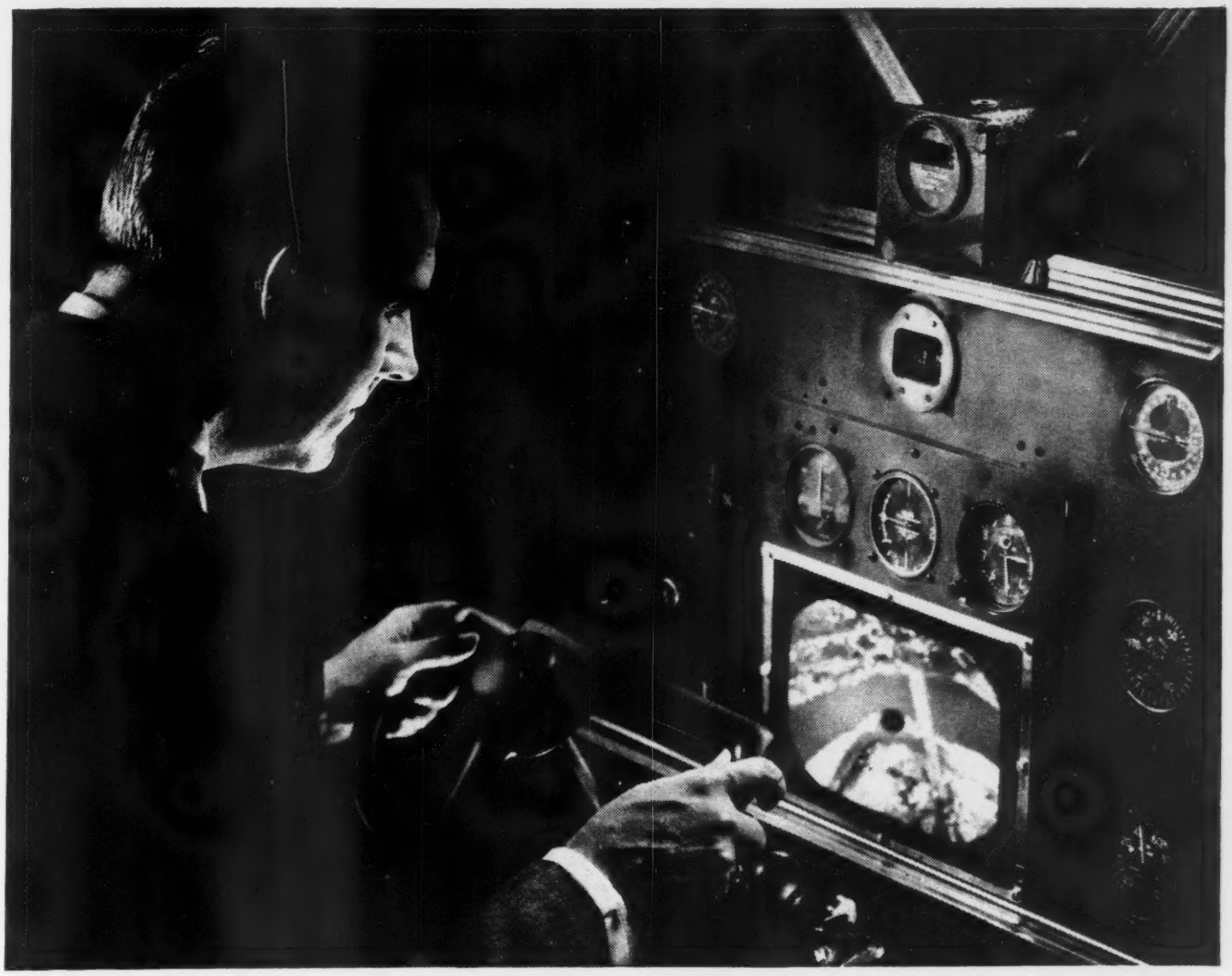
During the winter of 1942–43, it became more and more apparent to military people interested in bombing problems that, due to weather over the European continent, some method of putting the bombs on the target other than by visual means was necessary. Before radar made blind bombing practical, the Eighth Air Force was kept on the ground for a large percentage of the time, since in addition to the problem of take-off and landing, it was necessary to have clear weather over the target in order for the bombardier to use his visual sight.

The British had done some work with radar bombing and results had looked promising. Radiation Laboratory at M. I. T. had also been doing some work along these lines and so, at the urgent request of the Services, this work was intensified. Thus it was, that in the fall of 1943, about twelve B-17 airplanes equipped with the new radar equipments were sent to England. These were to be used as lead aircraft for combat formations, and it was planned that the formation would drop their bombs as directed by these lead aircraft. Personnel from Radiation Laboratory accompanied these planes to help introduce the equipments and techniques to the Eighth Air Force. These twelve equipments led the Eighth Air Force during the winter of 1943 and 1944.

In the meantime, a contract was placed with the Philco Corporation for production of such equipments in quantity. These production equipments went into combat use in the spring of 1944 to augment and replace the twelve overworked laboratory constructed units. Reports of personnel with the Eighth Air Force and research at Radiation Laboratory combined to form the basis for improvements on the equipments. This, combined with better operator training, furnished the Eighth Air Force not only with a device for accurately dropping bombs through overcast but also one which gave better and better results as time went on. The bombing effort of the Eighth Air Force became to a high degree dependent on radar, since the weather was such to preclude optical bombing a great deal of the time. This equipment was also used later in the same manner by the Fifteenth Air Force in the Mediterranean Theater of Operations.

Bombing the Normandy beachheads just prior to the landing of troops on D day was an important part of that operation. On that historic day, the coast of France was covered by fog and clouds to the extent that visual bombing on a large scale was impossible. Needless to say, the "Mickey" sets played an extremely important part in the D day bombing effort of the Eighth Air Force. This equipment was also used in the pre-invasion bombing of the southern coast of France by the Fifteenth Air Force. (*Continued p. 140*)

L. A. DuBridge, second from left, and Dr. Karl T. Compton, second from right, at a secret dinner several months ago in Boston



One of the many ways radar can serve aviation is by enabling the pilot to "see" through fog and darkness.

Radar—a "Moving Roadmap" for Flying

Pilots can now have an accurate radar "road map" of the earth below—showing landmarks and major details of terrain. Radar will make it a whole lot safer to fly at night or in stormy weather—as well as in broad daylight.

This is only one of the many possible uses for radar. For example, radar will "see" icebergs or islands many miles away—day or night—and enable ships to avoid them. It will provide man with an amazing new "sixth sense"—and will be used in a great many ways yet to be discovered.

RCA research and engineering played a leading role in developing radar. Similar research goes into *all* RCA products.

And when you buy an RCA Victor radio or television set or Victrola, made exclusively by RCA Victor, you enjoy a unique pride of ownership. For you know, if it's an RCA it is one of the finest instruments of its kind that science has achieved.

Radio Corporation of America, Radio City, New York 20. *Listen to The RCA Show, Sundays, at 4:30 P.M., Eastern Time, over the NBC Network.*

HOW RADAR WAS BORN

During RCA experiments at Sandy Hook in the early 1930's, a radio beam was shot out to sea. Men listening with earphones discovered that this beam produced a tone upon hitting a ship that was coming into the New York harbor.

Later on the question arose, "If radar could 'hear' couldn't it be made to 'see'?" So the viewing screen—or scope—was incorporated into radar. This scope is an outgrowth of the all-electronic television system that was invented and perfected at RCA Laboratories.

RCA **RADIO CORPORATION of AMERICA**

RADIATION LABORATORY

(*Continued from page 138*)

In addition to being a blind bombing device, the "Mickey," as it became known, proved to be a valuable navigational instrument, and allowed many a bomber formation to thread its way between flack areas while flying to and from the target.

In principle the "Mickey" set operates like the conventional radar. The result is a map of the area beneath the airplane. In addition to this, a computer is incorporated which takes such data as bomb ballistics, ground speed, altitude, and wind and computes from them the distance from the target at which the bombs should be dropped. It places a so-called "BRM" or "Bomb Release Marker" on the face of the cathode ray tube so that when the target reaches this marker, the operator knows the bombs should be dropped.

Ground Controlled Approach

"Imagine a 100-foot ceiling, less than a mile visibility, a strong cross-wind, severe turbulence, a hazardous obstacle about a mile away just off course. . . . There was no alternative — either us or the ocean." The GCA at Iwo Jima landed this B-29, low on gasoline and in bad shape after a raid on Japan, soon after we won that costly island, beginning a career of life-saving in the Pacific that turned spectacular emergencies into routine landings.

Late in 1941, the idea occurred to one of the original group of scientists at Radiation Laboratory, that the accurate information of height, azimuth bearing, and range of a target aircraft furnished by microwave radar could be applied to guide that plane along the correct glidepath to a safe landing. This required that a ground controller transmit by voice radio the instructions to the pilot, an idea counter to established procedure, and the preference of many older pilots and other aeronautical personnel. In preliminary tests with a number of pilots, their doubts were resolved when they learned to trust the high accuracy of the information, and the talk-down principle was first proved valid.

A large group at Radiation Laboratory then spent eight or nine months of intensive research and development to complete a prototype model. Trials brought further modifications and improvements, until in early 1943 the equipment passed exhaustive demonstrations and was accepted by the services.

That summer, while the prototype was sent to England for field trials at bomber bases, production engineering began with Radiation Laboratory supervision at several manufacturers on contracts for the Army, Navy, and RAF. Delivery of production units began early in 1944, in time to aid in the late phases of the war in Europe, and to carry a more prominent role in the Pacific. At present, GCA's are in operation in all parts of the world, working with tactical units, patrol wings, and along the far-flung airways of the ATC.

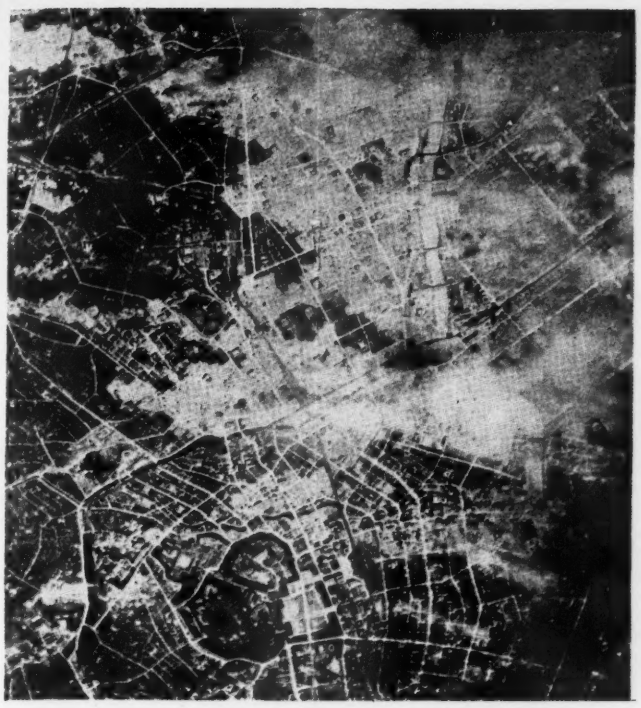
In its eleven-ton mobile trailer, the GCA includes two complete radar systems. With one, the operators search on PPI's (scopes showing a map-like presentation) the zone surrounding the airport, directing the air traffic approaching the field from all directions into the sector scanned by the second system. This system, a high-precision radar, giving practically continuous information on the plane's position, is used by the final controller to guide the pilot down the glidepath. One precision indicator shows the height of the plane and of all ground obstacles along the path, so that the plane can be kept a safe distance from buildings, towers, or hills; the other shows the plane's lateral position with respect to the runway.

Of the five-man operating crew, two at PPI's can select communications channels in all aircraft bands to direct traffic, and the final controller, at indicators showing error in azimuth and elevation from the correct glidepath, also, has complete radio facilities. Flanking the final controller, two trackers follow the course on the special precision indicators, and supply him with azimuth, elevation, and range data. The control and tracking procedure is easily adjusted to fit the flight characteristics of any aircraft type, fighters, bombers, cargo planes, or commercial airliners being handled equally well.

Ground radar offers an effective weapon in conquering weather, the foe of all air-borne activities. Teamed with early-warning systems, radar beacons, and other radar sets for the general surveillance of air traffic, GCA can provide widespread ground control of aerial navigation. Such a combination of equipment makes possible the first true all-weather airway, on which flights will operate on schedule with safety, despite weather which may require negotiating the entire journey without sight of the ground.

Sir Robert Watson-Watt, British "father of radar," visiting the M.I.T. labs

(*Continued on page 150*)



C. W. S.

(*Continued from page 113*)

problem by the mycologists here eventually found widespread military use.

Another important research project of the laboratory was the program to improve the available detectors of poisonous war gases and, if possible, to discover new ones. This project met with success, and a greater degree of sensitivity in gas detection was attained. This work culminated in the production of the Army's M-9 Detector Kit, weighing only two and a half pounds, by which the presence of any of the toxic gases may be discovered, together with an approximate estimation of its intensity or concentration. The sole production of one of these new detector agents was carried on at the Institute, supplying all of the Allied forces. Included in this project was the development of other detecting materials in the form of gas-sensitive papers, paint, crayons, and so on, involving simple color changes in the presence of the particular gas they are made to detect.

One incidental problem arose with the decision that our armies needed a chemical laboratory in the field, mobile and maneuverable, yet fully equipped. Our Development Laboratory designed such a unit capable not only of making special analyses of war gases and handling similar problems but also of serving as a general laboratory to handle any chemical problems which might be encountered in actual operations.

Liquid Flame

Probably the most spectacular achievement of the laboratory, and also one of the most effective, was made in the field of pyroballogy, where the discovery of a process to convert liquid gasoline to a semi-solid jelly brought revolutionary changes to the war of fire.

The problem as originally assigned was the development of an incendiary bomb better than Germany's best — the German magnesium bomb. At the request of the Army Air Forces, the Chemical Warfare Service

Results: Mark 69 fire bombs devastate the heart of Tokyo

began to investigate this, in collaboration with the technicians of the Standard Oil Company of New Jersey, even before the attack on Pearl Harbor. The requirements for this new type of incendiary bomb were simply that it must be "capable of being produced in mass quantities with readily available materials." Use of magnesium, the accepted incendiary material at that time, was eliminated by that latter requirement, since there was a serious shortage of that metal.

After a good deal of experimental analysis, a secret white powder was devised which, when stirred into ordinary motor fuel in the correct proportions, converts it into a material somewhat resembling raspberry jelly in appearance. This jellied gasoline, called "gel gas," proved to be a devastating weapon for destroying enemy industrial centers as well as for knocking out smaller fortifications and installations. Its original use was in what the Army called the M-69 — a fire-bomb about nineteen inches long and weighing six and a half pounds. The manufacture of this bomb proved so simple that it was produced in plants which formerly made fireworks, bedsprings, or wallpaper. In contrast to the sometimes elaborately machined German incendiaries, the shell of the M-69 is just squirted from a casting and looks something like a piece of rainspout.

The bombs were actually dropped in large five-hundred-pound "clusters" containing as many as sixty of the M-69's. This arrangement made for more accurate aiming of the incendiaries since the small individual missiles were not finally released until the big bomb opened to free its load down near the target. The individual incendiaries had streaming tails which slowed down their rate of fall to about two hundred and fifty

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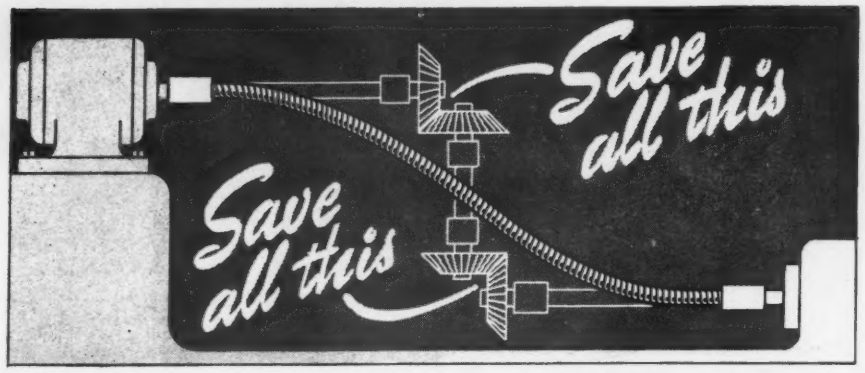
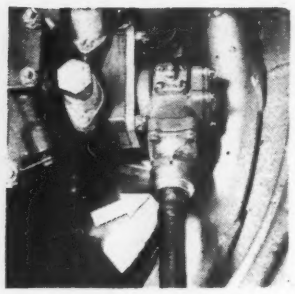
Special equipment was often developed for some projects

S.S.WHITE FLEXIBLE SHAFTS

"Metal Muscles" for Power and Control



They simplify manufacturing and cut production costs

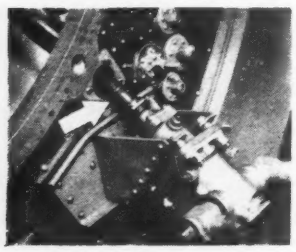


A typical S.S.White power drive flexible shaft application — aircraft fuel pump drive. Above—the geared take-off of the shaft from the engine, and below — the connection to the pump. Aircraft applications of S.S.White flexible shafts total millions of feet annually.

One of the rules in engineering design is to use the ***fewest parts*** that will accomplish a given purpose —for that means the product can be manufactured easier, faster and at lower cost.

Where your design calls for the transmission of rotational power around turns and in paths other than straight lines, the fewest parts that will do the job is an S.S.White flexible shaft.

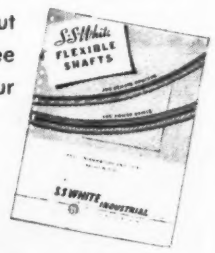
This is also true for mechanical remote control. A single S.S.White flexible shaft suffices for smooth, sensitive control between practically any two points.



S.S.White flexible shafts are produced in a large selection of sizes and characteristics in both the power drive and remote control types. A knowledge of the range and scope of both types will be helpful to you in engineering design work. As a preliminary step in acquiring this knowledge, follow the suggestion below.

WRITE FOR THIS BULLETIN

It gives the basic facts and technical data about flexible shafts and their application. For a free copy, write for Bulletin 4501. Please mention your college and course.



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CYCLOTRON

(*Continued from page 120*)

Self-excitation of the oscillator provides one of the most important features of the M. I. T. system; through its protection it is possible to drive the voltages to a point where continuous sparking from the dees rapidly cleans off adsorbed gases from the metal surfaces, resulting in higher vacua and higher voltage breakdown limits.

Vacuum System

The chamber must be kept at pressures below .01 micron. Two high-speed oil diffusion pumps, one under each dee line, are used to evacuate the chamber of the M.I.T. cyclotron. These pumps together give a pumping speed of about 3,000 liters per second at .01 micron. The oil diffusion pumps are backed by a Kinney mechanical pump which can pump the 3,000 liter vacuum system to the backing pressure of 10 microns in about one hour. Beginning with the whole system at atmospheric pressure, about three hours are required to pump it to a pressure sufficiently low to permit operation.

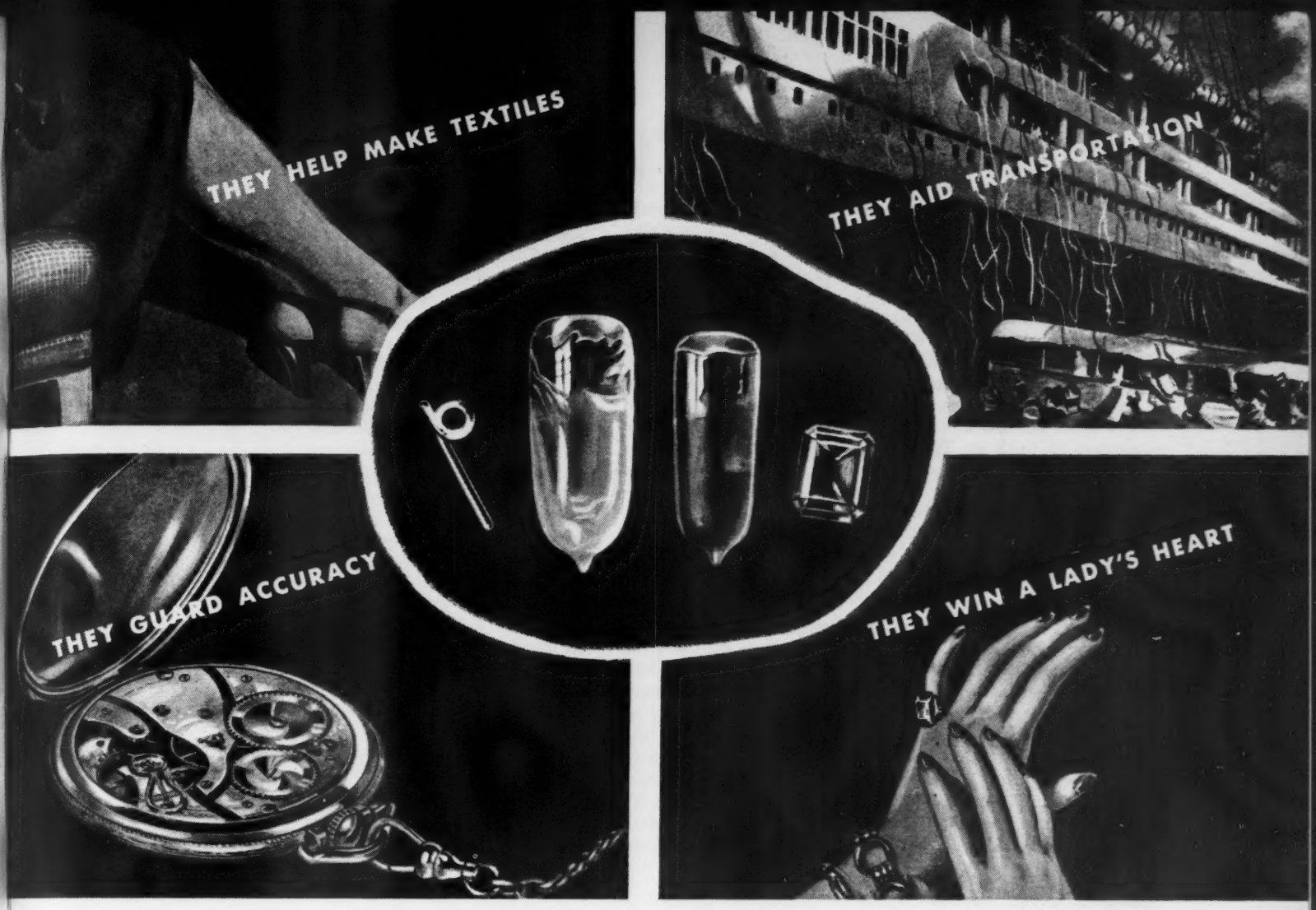
Because of this relatively long pumping time, vacuum locks are provided for changing probe targets and filaments without destroying the main vacuum. Probe targets and filaments are mounted on stems which can be slid through vacuum seals, and thus pulled into auxiliary chambers with gates to isolate them from the main vacuum system. In replacing the stems, the auxiliary chambers are pumped out before the gates are opened and the stems slid into place. Plates and ports are sealed by rubber gaskets held in machined grooves. Rubber gaskets have proved very successful in this cyclotron and have given trouble-free seals remaining tight indefinitely.

The ionization gauge is arranged in such a way with a multivibrator that a sharp increase in the gauge reading causes a signal from a speaker to increase sharply in frequency, obtaining a siren effect. One man, therefore, can hunt vacuum leaks by squirting ether and listening to the pitch of the signal from the speaker. Ether is used not only because it diffuses through a small leak faster than air, but because it causes marked increase in the filament emission of the ionization gauge.

Shielding

During operation, large amounts of *X*- and gamma-radiation, along

(*Continued on page 144*)



. . . *what else is in store for these Man-Made Gems?*

THAT'S A GOOD QUESTION. But at this point no one can give you the complete answer to it.

The full possibilities of these man-made gems have not been explored. The making of synthetic sapphire and ruby in this country is an infant industry—born in World War II.

Prior to the war, all our synthetic sapphire and ruby were imported. When our supply of these war-vital materials was cut off, THE LINDE AIR PRODUCTS COMPANY, a Unit of UCC, at the request of the government condensed into months the research necessary to master the techniques of quantity production.

Of all the gems, synthetic sapphire and ruby, like their natural forms, are second only to the diamond in hardness. Already they have many uses.

They are long-wearing thread guides in textile mills. They are the bearings in watches and delicate navigation instruments. They make phonograph needles that will far outlast metal. They are much in demand for jewelry . . . and are used for many types of cutting tools, gages, spray nozzles, burnishing wheels and insulators.

What else are they good for? If you are technically minded and read the italicized paragraph below, you may come up with a new answer or two.

LINDE SYNTHETIC GEM MATERIALS

In addition to extraordinary wear resistance and great beauty, LINDE synthetic sapphire and ruby are highly resistant to most chemicals and have high strength at temperatures up to 3,000 deg. F. and higher. Electrical losses at all frequencies are low. They can be given an exceptionally smooth surface, and can be bonded to other materials. Available in half-boules up to 150 carats, and in rods of 0.065 in. to 0.125 in. diameter.

For additional information send for the folder P-12 "Synthetic Sapphire Production."

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INDUSTRIAL GASES AND CARBIDE—The Linde Air Products Company, The Oxweld Railroad Service Company, The Prest-O-Lite Company, Inc.

CYCLOTRON

(*Continued from page 142*)

with dangerously large amounts of fast neutrons, are liberated by the cyclotron. Many cyclotrons are built underground or on mountain sides to shield operators from this harmful radiation. At M. I. T., however, the cyclotron is located near the main buildings and is shielded in a different manner. Water tanks place an effective water barrier between the cyclotron and the rest of the building. Water barriers are also used to shield the main buildings from the radiation, for the cyclotron upsets measurements in the radio-activity research laboratories. Special gloves and aprons are available for use when changing targets, but are very clumsy to work in. Target handling, therefore, is done as quickly as possible to minimize exposure. Live targets are usually kept and transported in heavy lead containers. In spite of the water barriers, enough radiation is present at the control panel to be measured, and in fact this is a sensitive method for tuning in the beam.

Controls

The M. I. T. cyclotron was designed for continuous operation in the production of radio-active isotopes. It is desirable to maintain a steady beam in the production of these isotopes, so that the total micro-ampere hours of bombardment on a target can be computed or measured. So many factors affect the stability of the beam, however, that it is difficult to maintain steady operation without the use of some automatic controls. The magnet current, for example, is held constant by an automatic control. After a short warm-up period, the position of resonance can be maintained for long periods of time.

Most of the controls for the M. I. T. cyclotron are mounted on a control panel located some distance from the cyclotron. The machine can be started up or shut down almost entirely from this panel. Two types of interlock systems are an important part of the control system. One type shuts things off in case of cooling water or vacuum failure; the other type prevents things from being turned on unless conditions are right for operation. For example, the vacuum interlocks turn off the oscillator power, ion source, deflector, and vacuum gauges in case of vacuum failure. Other interlocks require the magnet cooling water to be on before the magnet generator can be started, and prevent the oscillator power from being turned on unless the target cooling water is on, and the vacuum in good condition.

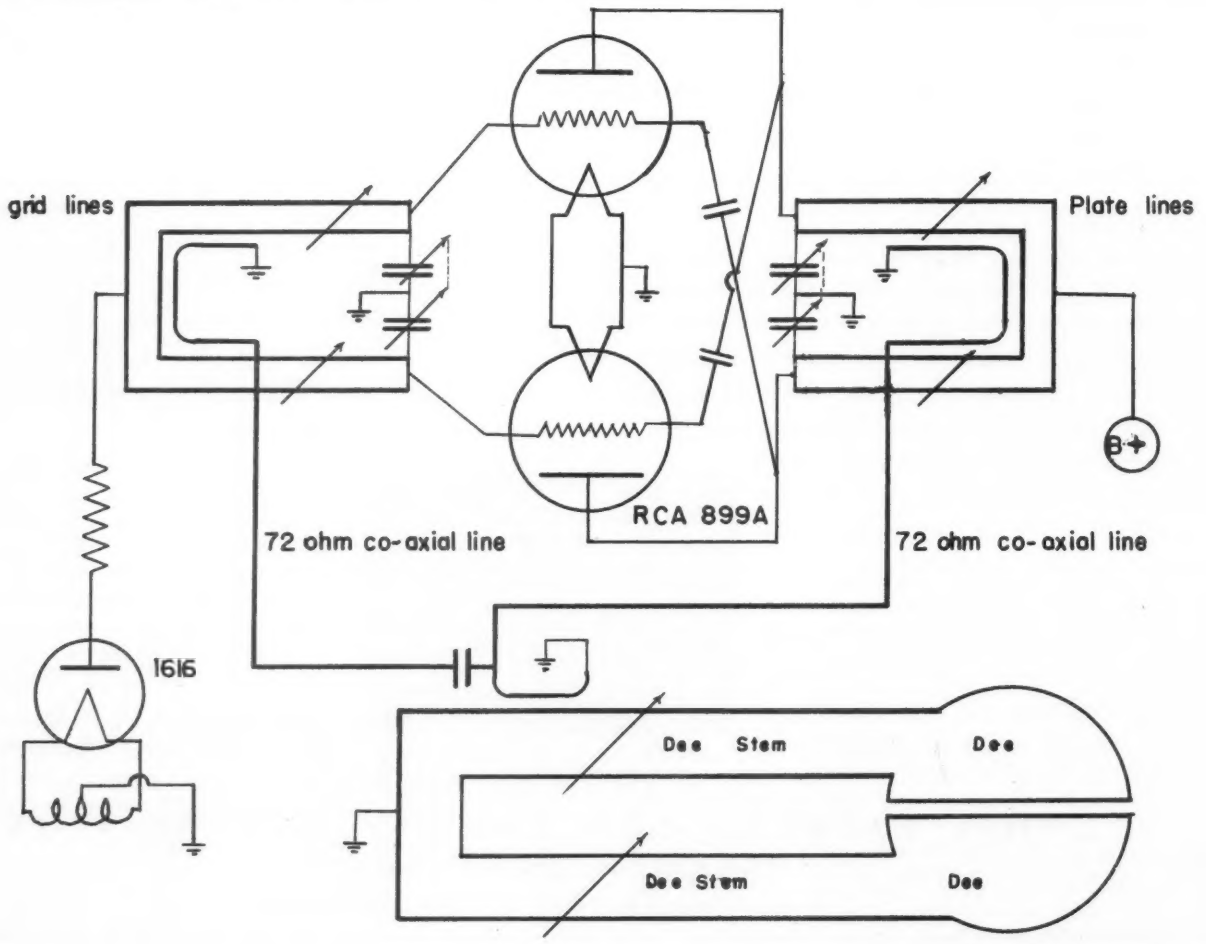
The outside beam current is measured directly but the probe beam current must be measured indirectly. The probe beam current is measured by thermocouples across the target cooling water, the beam current being proportional to the temperature gradient in the cooling water and to the flow of water through the target. The thermocouple voltage is amplified and drives a recording galvanometer and beam current integrator. Part of the amplified voltage is balanced in a bridge with a relay in the detector arm. The relay actuates a warning bell when the beam fluctuates, unbalancing the bridge.

The M. I. T. Cyclotron's Place in the War Effort

The radio-active isotopes produced by the M. I. T. cyclotron contributed much in the recent war effort. Large amounts of radio-active sodium, phosphorus, and iodine were produced for medical therapy and research. The whole-blood program of the Red Cross depended

(*Continued on page 150*)

Schematic diagram of oscillator and resonant circuit



To The

YOUNG ENGINEERS OF AMERICA

To those young engineers who are in the service—those who are at the drafting boards of industry—those who are preparing themselves for the engineering profession:

The "good-will" which attaches to a good name or trade-mark has often been appraised at many millions.

For the public places reliance and trust on those names which down through the years have proved they will faithfully reward that confidence.

The products the public trusts are the ones they buy. Where their heart is—there their business follows.

Such a tremendously valuable asset is not built up overnight. It comes only after arduous years of toil—of many disappointments—many triumphs and achievements. And once attained—an equally strong and effective effort must be constantly maintained to guard and protect the reputation thus earned.

Quality of the product—standards of workmanship—must be kept at the highest possible level—in line with the famous name which it bears. Performance in the hands of the user must live up to the highest standards he has been led to expect.

Industrially, one of the great names in America—a name recognized for its foresight, courage, progress and leadership, is the name Timken. The whole world moves forward on these advanced products.

You'll do well to learn the many benefits of Timken Bearings. For Timken Bearings have indeed been of prime importance in making life easier, smoother and better for all humanity.

The Timken Roller Bearing is one of the basic factors which made possible the efficient performance of our huge war machine. It will be vitally important to our vast peacetime economy at which the whole universe will marvel.

In addition to Timken Bearings there are Timken Alloy Steels used for many highly specialized applications and Timken Rock Bits which have revolutionized modern mining and construction.

The Timken Company has spent millions in research and technological improvements so that millions of Americans may enjoy a better life—so that engineers like yourself can rely implicitly on each Timken product—each Timken recommendation.

Engineers have at their disposal all of the facilities of this organization which is the world's foremost manufacturer of anti-friction bearings.

This company offers unlimited opportunity to many young engineers. Maybe you might like to come with our organization. We will welcome applications from engineers who feel that they may fit into a company such as ours.

The old proverb—"Deviate an inch and you lose a thousand miles"—is a sound thought for young engineers to bear in mind. There is one thing as steadfast as the North Star—Timken Bearings are steadfast in dependable performance.

Everyone knows dependable performance is a basic requirement of mechanized America. Millions of wheels and shafts are turning faster, more accurately, more freely, and longer, because of the inherent qualities of this precision product.

It has been truly said that the trade-mark Timken incorporates all there is in Bearings. See that the trade-mark "TIMKEN" is on every bearing you use.

THE TIMKEN ROLLER BEARING COMPANY

CANTON 6, OHIO

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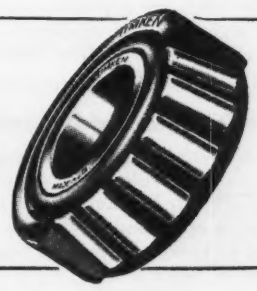
TIMKEN  **BEARINGS**

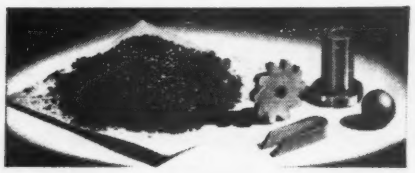
Guess how many miles of thread he's wearing!

LET'S unravel the man—garment by garment! When we do, we find it takes about 58 miles of thread, of one kind or another, to dress him from the skin out.

Better than 9 miles for underwear; 2½ miles for socks; 10 for a shirt; 1 for a tie; 35 for a suit. So the manufacturers tell us.

And remember, every inch of *all* the thread that is woven into fabrics has to run at high speed through metallic guides on the textile machines.

Those guides are ordinarily made of hardened or chrome-plated steel—but they wear out fast.



Now mill owners are turning to a new miracle metal, "the hardest metal made by man." It is called Carboloy Cemented Carbide. And mill men have discovered that Carboloy textile guides often outlast steel as much as 50 to 1.

What is Carboloy? It starts out as a simple mixture of metallic powders, but tremendous heat and pressure transform it into a metal of almost diamond hardness.

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In cutting tools, in dies for drawing wire and tubing and forming sheet metal, it has played a major role in war production—commonly tripling the output of machines and men; speeding tank, ammunition and naval building programs.

After the war, the benefits of this new miracle metal will be available to everyone! Countless products will be made better and cheaper through the wider-spread industrial use of Carboloy tools and dies.

More than that, the use of Carboloy for wear-resistant parts in airplanes, automobiles, home appliances and equipment, will give these products themselves improved performance and longer life.

Attention Engineers and Designers

Carboloy research and field engineers will gladly help you take full advantage of the hardest metal made by man in planning your postwar product and production program. Write us today. Carboloy Company Inc., Detroit 32, Mich.

Even your clothes have felt the effects of a wonderful new metal—the hardest metal made by man. Carboloy Cemented Carbide has helped revolutionize industry—and promises great benefits to everyone in the near future.

The Hardest Metal Made by Man

CARBOLOY

CEMENTED CARBIDE

THE FLAME THAT CUTS *through Sea and Steel*

Men-of-war that "died" at Pearl Harbor lived again to fight at Omaha beach and Leyte. No small measure of credit for their resurrection belongs to the modern techniques of underwater cutting with the oxy-hydrogen flame and underwater welding with the electric arc. These methods are serving the nation's needs in wartime, and are also opening the way to new peacetime accomplishments in submarine salvage and construction.

Air Reduction has played a leading part in designing and manufacturing equipment for underwater cutting, as part of its program of progress which has given the world many new developments in welding, cutting and other related methods for modern metal-working.

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● How does an engineering student eventually become vice president or head of a company? What—over and above his technical education—must he know to qualify as a top executive?

The answer is: a basic understanding of practical business principles and methods.

It is this PLUS knowledge that enables him to see beyond the specialized activities of one department—to grasp the importance of Marketing, Finance and Accounting as well as Production.

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There is a scientific quality about the Institute's Course and Service that appeals to technically-trained men. That is why there are so many prominent members of the engineering profession among the more than 400,000 subscribers. They include: J. W. Assel, Chief Engineer, Timken Steel & Tube Co.; Lewis Bates, Plant Mgr., E. I. du Pont de Nemours & Co.; Lewis P. Kalb, Vice President, Chg. Eng. & Mfg., Continental Motors Corporation; H. W. Steinkraus, President, Bridgeport Brass Co.

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Among the prominent men who have contributed to the Course and Service are: Thomas J. Watson, President, International Business Machines Corp.; Frederick W. Pickard, Vice President and Director, E. I. du Pont de Nemours & Co.; Clifton Slusser, Vice President, Goodyear Tire & Rubber Co.

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C. W. S.

(*Continued from page 141*)

feet per second, fast enough to penetrate the roof of a factory or house, but yet not so fast that the mechanism of the bomb was impaired by the impact. Thus the M-69 carried its flame inside the target and was able to destroy many supposedly fireproof buildings because of this feature. Once on the floor of a factory, a five-second time fuse allowed the M-69 to fall on its side before its flaming core of jellied gasoline, burning at 3000 F., was hurled from the tail for distances ranging up to a hundred feet. Resting in the aisle of an enemy factory, such a bomb had an excellent chance of spewing its fiery charge onto inflammable material, in contrast to the German incendiary bomb which usually could cause damage only if it fell directly upon combustibles. This ejection feature made the M-69 unique among incendiaries.

When finally put into use against Japan in our huge B-29 raids, the new fire-bomb left vast seas of high, wind-whipped flames, visible from more than a hundred miles away. Reports were heard of a mad exodus of the civilians from the burned-out hearts of Japan's great cities. Kobe, Osaka, Tokyo — aerial photographs show the record of a vast pattern of destruction.

Soon after the first development of gel gas, the idea was conceived that this new munition might also prove useful in flame throwers as well as in the incendiary bomb. Before this innovation, the flame throwers of all nations, both Allied and Axis, were not improved basically over those used in World War I. Their range was so limited that soldiers had to approach within less than fifty feet of the target in order to use them. Almost ninety per cent of the fuel burned on the way to the target and created a huge, billowing flame which might be blown back upon its director by a sudden puff of wind. Flame throwers were useful for such things as burning away foliage, but their many limitations greatly restricted effective combat use.

This new semi-solid fuel, however, soon proved to be the solution to all the previous difficulties. The heavy, thick rod of gel gas, when shot from the flame thrower, carried accurately to distances up to a hundred and fifty feet; and, in addition, even at maximum range more than seventy per cent of the fuel carried through to the target. Flame-thrower fuels and guns were investigated by several groups at the Development Laboratory, and the characteristics of jellied gasoline were studied in order to produce the best flame under many diverse situations. Because of this work, by early 1943 our soldiers in the Pacific were able to silence enemy strong-points which had resisted massive naval and aerial bombardments.

It was found that the thin stream of burning gel gas from the new M1-A1 flame thrower could be aimed just like a stream of water from a garden hose, in contrast to the clouds of fire from the previous weapons. An interesting aspect of this new weapon was disclosed with the discovery that it could fire "around corners." The carrier of the flame thrower could advance on the flank of a pill box, out of range of the enemy fire, and was able to direct the heavy stream of his weapon against the inner sides of the gunport or embrasure, from which the burning fuel ricocheted into the interior, immobilizing the fortification with its searing flame.

It was this deadly weapon which cleared a path for our soldiers upon the beaches of Normandy and the sandy atolls of the Pacific.

In connection with the flame-thrower experimentation at the laboratory, an indoor firing range was set up in an abandoned factory at Lawrence, Massachusetts. The place had once been a thriving mill but had been put out of operation by cheap Japanese competition in the thirties. The room used for the tests was a long, vast space with concrete beams and floor and brick walls. The shadowed rafters high overhead and the gloomy corners lighted only by the flickering flames of the weird operations below almost seemed peopled with the spirits of by-gone workers, grimly enjoying the scene of eventual retribution before them. Here the actions of the new fire-weapons were investigated under highly diversified conditions, and new methods of operation decided upon.

The laboratory not only worked on the development of the new fuel but also devised new guns for projecting it, both for mechanized units and for portable use. Many of the details of construction and operation of these weapons still remain veiled by military secrecy, as do the records of some of the other projects, kept safely for a day when they may be needed again. In this category is all the data on the research in poison gases, deadly information which fortunately never had to be put into actual use.

(*Continued on page 150*)

Economies

Born Of War Industry Have Their Rewards TODAY...

● Fearful of being "too late with too little," American industry won its race against time. Quantity and quality surpassed the hopes of all but the most courageous and progressive.

One of the contributing factors to victory was the *general advancement in mechanical materials-handling,* and most particularly in routing materials in process through successive stages of manufacture. Substantial savings in manpower, time and costs accrued. Production consistently increased, meriting a steady flow of "E" awards.

Lamson Conveyors, through many ingenious applications, devised by Lamson engineers, showed industry throughout the length and breadth of the country, new speeds and economies in materials-handling.

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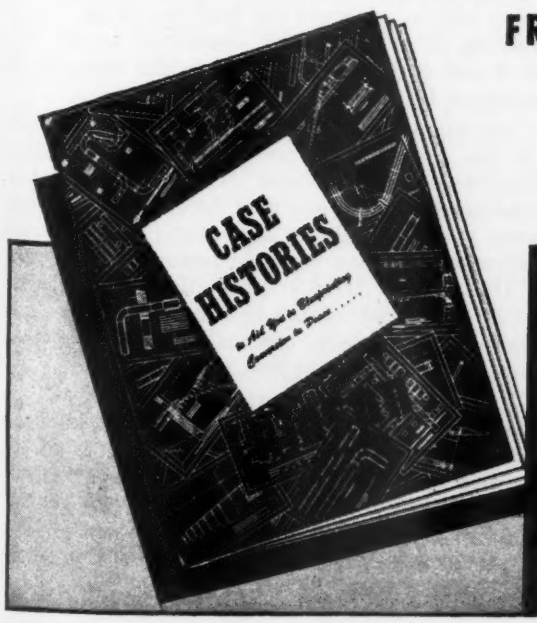

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RADIATION LABORATORY

(*Continued from page 140*)

Radiation Laboratory Field Service

It was recognized early in 1943 that the operational success of the new microwave radar equipment in the European theater would require the presence in the field of civilian experts who had worked on its development. For this purpose the British Branch of the Radiation Laboratory was organized in the fall of 1943 to assist the strategic air forces under General Carl A. Spaatz in the acquisition and improvement of radar bombing equipment and to work with the tactical air forces in the perfection of radar control of offensive fighter sweeps.

In Italy a small group of Radiation Laboratory men working closely with the Radiation Laboratory and BBRL assisted the Fifteenth and Twelfth Air Forces in corresponding programs.

During this time the Radiation Laboratory was rendering similar assistance on the introduction of new radar equipments in other parts of the world. New Navy radar ship equipment was often accompanied on shake-down cruises and first operations by Radiation Laboratory personnel. In Australia a small team of specialists worked with the Radiophysics Laboratory on the introduction of microwave techniques and on problems on radar propagation. When the Japanese surrendered, Radiation Laboratory personnel were working in various parts of the Pacific and the Far East.

Today the Laboratory is preparing to close down. A large part of its developments are necessarily of a sort that cannot be got into the field for many months. Already on its boards, or in pre-production stage, are enough radar types to keep the armed services ahead in the field for at least another year.

Research is transferred to Army, Navy, and industrial centers. Preparations are being made to release the staff.

Many members of the staff will stay behind long enough to complete the Laboratory's last major project: the preparation of a carefully planned series of books covering the progress in the field of electronics which wartime radar work has brought. Over the next two years, some twenty-five volumes will be published for public sale. These will cover the theoretical and experimental basis of the new electronics from every important angle.

It is estimated that in their five years at the Radiation Laboratory these men pushed research in this field ahead by at least twenty-five normal peacetime years.

CYCLOTRON

(*Continued from page 144*)

upon the large amounts of radio-active iron produced at the Institute. This iron was used in determining the condition of the blood. Many other materials were prepared for use in research, but restrictions forbid mention of them.

Future of the Cyclotron

At present there are two distinct uses for the cyclotron — as a producer of artificially radio-active isotopes in useful amounts, and as a tool for investigations in the fields of high energy and nuclear physics. Today radio-active isotopes can be made only by cyclotrons, though in the near future it is expected that a large amount of this work will be taken over by uranium piles developed during the war. As a scientific tool, then, cyclotrons should come into their own again as the burden of isotope production is lifted. Much work can be done on the study of the reactions of nuclei (with high-speed ions, for example) to help clarify our understanding of the fundamental make-up of atomic nuclei.

Though other types of accelerators have been built or proposed, it is still important to solve the problems inherent in cyclotrons, to try to raise the current and energy limits to even higher values. Only through continued progress will the cyclotron remain where it is now — one of the most important tools of modern science.

For more specific descriptions of the M. I. T. cyclotron, the reader is referred to Dr. M. S. Livingson's excellent articles in *Journal of Applied Physics*, Vol. 15, No. 1, January, 1944; and *Journal of Applied Physics*, Vol. 15, No. 2, February, 1944.

The writer wishes to thank Dr. E. T. Clarke for his invaluable aid in preparing this article.

C. W. S.

(*Continued from page 148*)

The work of the laboratory was not confined to the experimental stage alone, but was carried on into the factory when necessary, with "assistance given on the production lines." New testing instruments and improved methods of analysis were devised. Facilities were built to reproduce desert, tropical, or arctic conditions for testing purposes. Included in the chemical engineering program were the construction and operation of several pilot plants, one of which was carried to a semi-works scale and produced several tons of product a day.

On October 1 of this year the activities of the laboratory were officially brought to a close. The records of its work and the projects to be continued in the years to come have been transferred back to the Edgewood Arsenal; and Lieutenant Colonel Willard Slagle, the commanding officer, returned the building to the Institute. Building 12 is now being converted to the use for which it was originally intended — the training of future engineers for our chemical factories.

There are possibilities of numerous postwar applications of the research and development done here. The anthropological survey and its records will prove of use in the production of any gear for the face or head. The various rubber products and protective clothing will doubtless be of value to us in peace as they were in war. One of the Army's most effective weapons, D.D.T. — as deadly to insects as the atom-bomb was to the Japs — is already in full-scale commercial production and available for civilian use.

M. I. T. gave more than floor-space to the C. W. S. Development Laboratory — it gave what was far more important: the brains of its staff, the services of its graduates, and the full coöperation of the entire Institute. This unit was a typical example of the potential applications of Science to the problems of our world, and it is one more of the many reasons for our pride in M. I. T.'s war record.

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CUBIC FEET OF GAS

*used industrially and commercially in year**

Prove

The Trend is Definitely to GAS

FOR over thirty years, the records show there has been an increasing trend to Gas for all industrial and commercial heat requirements. The last ten years have been most spectacular, use of Gas in these fields having doubled. The twelve months ending June 30, 1945 saw the staggering figure of *one trillion, four hundred fifteen billion, eight hundred fifty-three million cubic feet of Gas* consumed by industrial and business establishments.

Nor was this due to war demand alone, for a large percentage of this ten year growth was attained before hostilities opened. Reasons for this wide acceptance of Gas by production managers and executives is seen in the merits of this modern fuel and the great advances made in scientifically designed Gas equipment.

The characteristics of Gas that make it so desirable to industry and business include its speed, economy in unit and overall costs, its precise automatic control, its cleanliness and dependability.

The story of the many advantages of Gas and the data on the specific type of heat transfer equipment that will do the most exact job is available from the Industrial Engineer of the local Gas Company.

**For 12 months ending June 30, 1945. Figures do not include Natural Gas sold for generation of electricity.*

AMERICAN GAS ASSOCIATION
420 Lexington Avenue, New York 17, N. Y.

THE TREND IS TO GAS
FOR ALL INDUSTRIAL HEATING

SKF
Puts the RIGHT BEARING in the RIGHT PLACE

FROM TANK TO TABLECLOTH . . .

The giant rolling mill that flattens out steel for armor plate and the household mangle your wife uses to iron sheets or table linen may not seem to have much in common. But the underlying principle of both machines is the same. Each employs rollers seated in anti-friction bearings—bearings such as are made by SKF.

SKF makes ball and roller bearings for many different needs. There never was a single bearing that could perform all the tasks that call for anti-friction bearings today. But wherever wheels or shafts present their own peculiar problems of speed, load, radial pressure and thrust, SKF is sure to have the particular type of bearing to do the particular job.

Whether you are seeking to speed up your production for the final drive of the war or are planning reconversion to postwar operation, an SKF engineer will gladly help you select

THE RIGHT BEARING FOR THE RIGHT PLACE

SKF INDUSTRIES, INC., PHILA., PA. 6006

ALL APHRODITE NEEDED...WAS A PERMANENT WAVE !!

NOT EVEN a Grecian Sea-Goddess can make with the glamour, if lank, dank locks cramp her style. Sleek, golden undulations are dreamy—but definitely.

With a sharp permanent, Aphrodite could probably have pitched big-time woo on Olympus with Ziggy Zeus himself. The old rug-cutter!

All the intricate parts of a permanent wave machine—including the aluminum —were on earth when Aphrodite made her breath-taking entrance in a sea-foam bubble gown . . . but even the oracle at Delphi lacked the sapience to imagineer them.

We invented the word "Imagineering"* to describe how Alcoa, and other great groups of technicians go about the job of supplying the methods, materials and machines of modern life.

Today . . . Youth laments that there are no new lands to discover, no new frontiers to cross. And yet, in the uncharted Kingdom of the mind, hardy pioneers are daily spanning new horizons in the twin fields of invention and adaptation. Aluminum offers exciting new opportunities to every intrepid Imagineer . . . who seeks new industrial worlds to conquer.

ALUMINUM COMPANY OF AMERICA
Gulf Building Pittsburgh 19, Pa.

*Imagineering equals the union of imagination, man's oldest mental development, and engineering, his newest. Together they are the key to progress.

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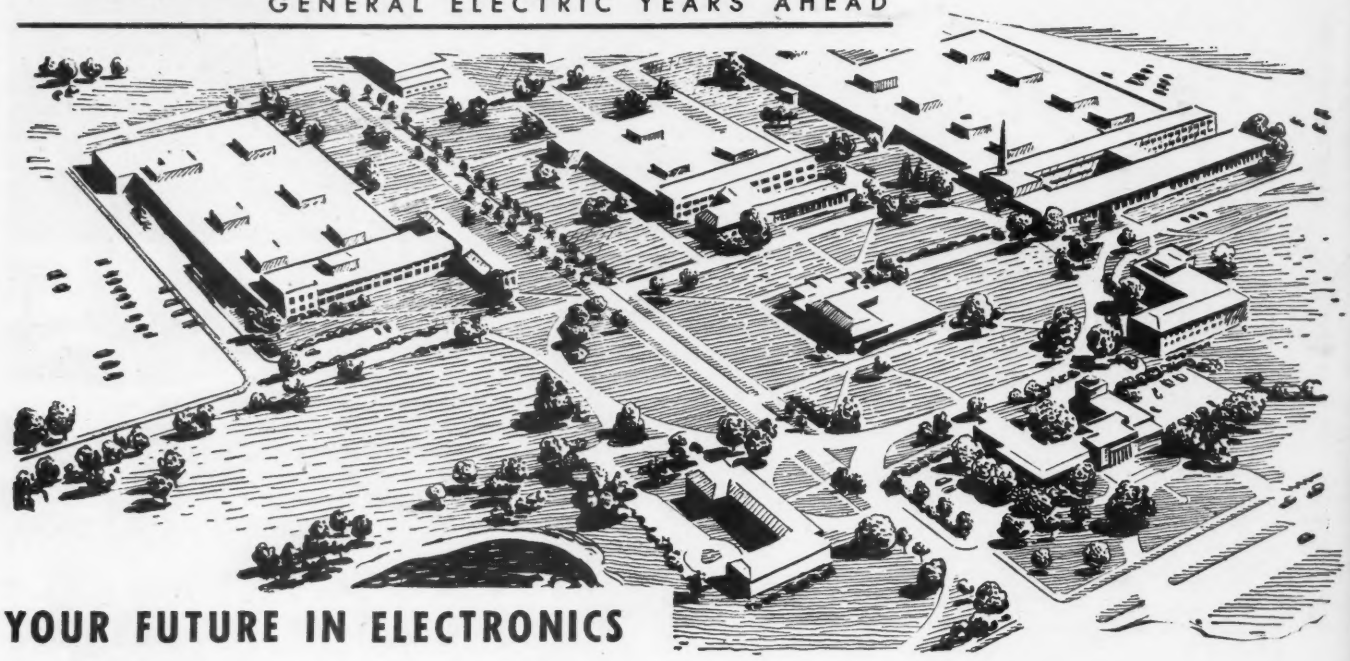
RESEARCH AND ENGINEERING KEEP GENERAL ELECTRIC YEARS AHEAD



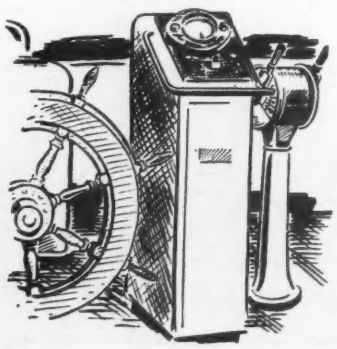
YOUR FUTURE IN ELECTRONICS

Housing A New Industry

Electronics, always just around the corner before the war, is now full grown. During the war itself it was almost a million-dollar-a-day business at General Electric. Now G.E. has begun construction of "Electronics Park" at Syracuse, New York, a 155-acre plant that will build television receivers, commercial radar, and frequency modulation radio for peacetime. Laid out like a college campus, this plant will have every modern facility for the design, development, and manufacture of electronics products. The men who work there will be part of one of the greatest industries to turn from war to peace.

Peacetime Radar

The first practical application of wartime radar is the G-E "Electronic Navigator." This will revolutionize "thick weather" navigation, providing the mariner with an instrument to plot a safe course, even through darkness, fog, smoke, or rain. Radar waves sent out from the ship's antenna can travel with the speed of light—in a millionth of a second make a round trip to an object 200 yards away. The pilot can tell, not only his own position but that of the other ships, buoys, lighthouses, and land around him.

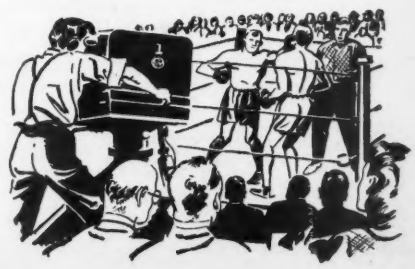


Television As A Career

Today nine television stations are operating throughout the country; one of these, WRGB, is owned and operated by General Electric. G.E.'s electronic engineers predict that by 1950 there will be 150 stations serving over 67 million people.

A television studio includes all equipment which is now part of a regular broadcasting studio, besides much more apparatus to take the pictures and allow them to be broadcast. The maintenance of this apparatus affords a great opportunity for the technically-trained men with a knowledge of basic principles of electrical engineering, electronics, and radar.

As electronics grows and branches into even more fields, the demand for trained personnel will increase.



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